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Table of Contents

Table of Figures

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EXECUTIVE SUMMARY

This document provides the highlights from the GARPUR Final Conference, arranged in Brussels 17-18 October 2017, where around 130 participants from policy makers, regulators, system operators, technology providers and academic experts were gathered to have the results presented and to discuss them. After 4 years of work GARPUR has designed, developed and assessed new probabilistic reliability criteria for the pan-European power system and its evolution beyond 2020. GARPUR has also evaluated the relevance of the criteria and their practical use, while seeking to maximize social welfare.
The new criteria are developed for system development, asset management and system operation to ensure a consistent treatment of reliability across all time horizons.

DAY 1 of the GARPUR Final Conference primarily targeted the **experts** in different organizations (TSOs, DSOs, academics, energy and technology providers) and presented the **major results of the project**. The objective of this day was to give the audience a detailed insight in the produced results and how they were achieved by GARPUR.

DAY 2 of the GARPUR Final Conference targeted especially **high-level decision makers** from both regulators and TSOs as well as policy makers from European organizations as for example ACER/CEER and ENTSO-E. This day allowed both GARPUR and other stakeholders to present and discuss their **general opinion on and challenges for implementation of a probabilistic approach for reliability management** on a strategic level.

Altogether the response and discussions showed that the audience was positive to the thinking and concepts presented by the project. Poll results show that more than the ¾ of the conference audience believed that all stakeholders are ready to start the implementation of probabilistic reliability management already now, or soon, and more than the ¾ believed that the main responsibility to lead the further work with probabilistic reliability management lies with the TSOs and ENTSO-E.

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1 BACKGROUND AND INTRODUCTION

Historically in Europe, power system reliability management has been predominantly relying on the "N-1" criterion – whereby the system should be able to withstand at all times an unexpected failure or outage of a system component – in such a way that the system is capable of accommodating the new operational situation without violating security limits.

Today, the increasing uncertainty of generation due to intermittent energy sources, and the growing complexity of the pan-European power system, increases the need for new reliability criteria – with a better balance between reliability and costs.

In this perspective, the GARPUR EC-funded project was launched in September 2013. Coordinated by SINTEF Energy Research, the project unites 7 TSOs, 12 R&D providers and 1 innovation management expert. After 4 years of work GARPUR has designed, developed and assessed new probabilistic reliability criteria for the pan-European power system and its evolution beyond 2020. GARPUR has also evaluated the relevance of the criteria and their practical use, while seeking to maximize social welfare.
The new criteria are developed for system development, asset management and system operation in order to ensure a consistent treatment of reliability across all time horizons.

This document provides the highlights from the GARPUR Final Conference, arranged in Brussels 17-18 October 2017, where around 130 participants from policy makers, regulators, system operators, technology providers and academic experts were gathered to have the results presented and to discuss them.

For more background, please see the GARPUR webpage, www.garpur-project.eu.

Here you can find a short **film** presenting the project, a **brochure** and the **project recommendations** (deliverable D9.1) and **roadmap for migration** (deliverable D9.2).

Further, all public deliverables can be found in the "Deliverables" section.

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2 DAY 1 HIGHLIGHTS

DAY 1 of the GARPUR Final Conference primarily targeted the **experts** in different organizations (TSOs, DSOs, academics, energy and technology providers) and presented the **major results of the project**. The objective of this day was to give the audience a detailed insight in the produced results and how they were achieved by GARPUR.

It focused on the technical level and the presenters were experts from GARPUR that have participated in the work. The main results regarding the reliability management framework, methods and approaches for different time horizons were presented this day, including the pilot tests and the GARPUR Quantification Platform (GQP) and validation of GQP. Recommendations for further work were also presented and debated.

2.1 Welcome and introduction

In his opening remark **Petter Støa**, Research Director at SINTEF, pointed out that work with probabilistic methods for TSO applications have been going on for more than 30 years. There is a gap between the methods described by academia and those applied by TSOs, but GARPUR is an important step to close it. At the same time, industry challenges are big and complexity of the tasks are high, and we still have a lot of work ahead of us. Nevertheless, the two waves of renewables and digitization cannot be stopped, and we are working towards a sustainable, affordable and secure power supply for Europe.

Patrick Van Hove, Project Officer for GARPUR from the European Commission, put GARPUR in perspective of the European policies. EU is committed to energy transition. A secure energy supply is one of the five main pillars of Energy Union policy, along with energy efficiency, renewables and market-based allocation of resources, and research and innovation to prepare the future. He further reminded us that GARPUR is one of the results of TSOs and DSOs coming together 8 - 9 years ago to plan R&I activities. The resulting initiatives have taken two different directions: one is to improve the hardware, another the software, i.e. how to better utilize the existing and future grid. GARPUR is one of the latter projects. The future of the energy system is challenging and uncertainties are increasing, energy supply and consumption is getting more and more fluctuating. On this background, the GARPUR approach is welcome, and we now need to apply it in day to day life of the transmission system operators. This implementation will be the real proof of research.

The GARPUR project was then introduced by **Oddbjørn Gjerde**, Research Manager at SINTEF and Coordinator of GARPUR. He reminded about the background of GARPUR starting with the limitations of the N-1 criterion which historically has been, and still today is, the cornerstone of transmission system reliability management. The work of GARPUR has aimed to overcome these limitations by defining new criteria for the future management of transmission system reliability, taking into consideration the probabilities and consequences of failures, and considering the social welfare effects. The main results of GARPUR are methods and tools to balance reliability and economy, making it possible to utilize the power system in a better way. The strong engagement of TSOs in the project was highlighted.

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2.2 Probabilistic framework for reliability management

Gerd Kjølle, Chief Scientist at SINTEF, introduced the two speakers for this session. She explained that they will present the theory of the GARPUR approach, split into a presentation of the development of the new reliability criteria and the socio-economic assessment.

The first speaker was **Efthymios Karangelos**, Postdoctoral Research Associate, at University of Liege. He presented the GARPUR Reliability Management Approach & Criterion (RMAC) as resulting from the project. Its different components; the Reliability target, the Socio-economic objective, the Discarding principle, the Relaxation principle, and the Temporal coherence proxies were introduced and explained. The GARPUR RMAC is a unified approach across all time horizons and decision-making contexts. The fundamental components are developed in the common model of reliability management as a multi-stage stochastic programming problem, and declined to any problem instance, from long-term and system development, through mid-term and asset management to short-term planning and operation.

Friðrik Mar Baldursson, Professor at Reykjavik University, was the second speaker. His presentation was on Socio-Economic Impact Assessment (SEIA). A main challenge is that you can trade quantity of electricity, not reliability of electricity. And it cannot be optimal to establish a 100% reliable system as this will lead to infinite cost. The objective of the SEIA is to quantitatively evaluate socio-economic impact of different reliability management criteria and approaches, focusing on socio-economic surplus as the key economic measure of impact. The SEIA quantifies surplus as the difference between (monetised) benefits and costs for stakeholders. Also, it was reminded that a lot of data is needed, as well as a good quality of the data provided.

Questions and answers
The discussion following the two presentations was led by Gerd Kjølle. The first question concerned data need and multi TSO interaction. There is no doubt that the GARPUR methodology requires more data than the N-1 approach. Luckily availability of data is increasing, as well as methods and techniques to deal with the (big) data. It is likely that this can be solved. High quality data will also be needed, as well as good quality assurance of data. Multi TSO interaction is undoubtedly considered an important aspect, regardless of the chosen reliability approach. A challenge here will be complexity and definition and agreement of type of exchanges, as well as legal and regulatory aspects. A follow up question was again on the data quality. Failure probabilities as well as data on value of lost load (VoLL) may be imprecise. To the question “Do you think it is important to take the uncertainty of the data into account?” It was replied that we should not put it explicitly into the methods yet, but do sensitivity analysis on the data using the current methods.

It was asked about the possible cost of bad reputation due to failures, a question often heard from "sceptical people". It was confirmed that this certainly is a cost to the company if it occurs. It is not included explicitly in the model today, and it is not clear whether is it a transfer cost or a real cost. It may be a real social capital cost.

It was commented on the system operation guidelines that entered into force in September 2017. They provide some requirements to data, outages and power quality, which might be good. Clarification questions followed on the ultimate goal of GARPUR. Is the goal of GARPUR to provide the same reliability as we have today, with lower costs? Or more reliable with the same costs? It was replied that the GARPUR methodology makes it feasible to quantify the reliability level and the socio-economic impact of different approaches, while with N-1 we usually do not calculate the reliability level.

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It was asked whether the reliability provided with the N-1 criterion is too high and too costly (system is "too safe"), and stated that the RMAC may be too complex for an operator, and how to move decisions from human operators to automation. In the discussion, it was reminded that the complexity comes from the problem, not from the solution, and that the GARPUR tools in the first stage will support the operators in their decisions rather than require automation.

It was also asked how the proposed approaches would work in an interconnected system? On the technical side, if we have different reliability targets what would be the effect and would we need to harmonize the targets between the countries? It was replied that if one takes the tool to its limits one will end up with conclusions like cutting off the low-cost customers. Fairness will need to be considered. A possible solution could be to use proxies to model mutual impacts of actions in different control zones.

2.3 Application in TSO's reliability management tasks

This session was introduced by **Irís Baldursdóttir**, Vice President at Landsnet. The topic to be presented and discussed is how the GARPUR methodology can be applied by the TSOs.

Irís Baldursdóttir, was also the first speaker. Her presentation was about the GARPUR methods applied to real-time and short-term operations, and she also presented lessons learnt from pilot tests at Landsnet. She reminded about today's challenges in system operation, the transmission system is a complex system in a complex environment, and characterized by the interaction of humans, the cyber system and the physical system, all with their related risks. The Landsnet pilot test has shown that the GARPUR methodology is able to give a quantitative answer instead of a yes/no answer to the reliability question, providing a higher resolution to risk assessment and thereby improved risk management. Further, quantifying risk in socio-economic terms allows for easier communication to non-technical stakeholders, and for direct cost-benefit analysis in risk management. The importance of data collection and data quality when probabilistic reliability approach is applied was highlighted.

The session continued with a presentation from **Pascal Tournebise**, R&D Engineer at RTE. Drivers and barriers to move towards an improved RMAC was discussed, and it was highlighted that this migration necessarily is a step by step process considering reliability and economic gains, performance and tractability, R&D, tools and data progress, as well as the need for harmonization between the TSOs. The test results confirm that the probabilistic RMAC could be more efficient than the N-1 approach, in the sense that it can provide better economy without increasing the real-time residual risk. It was also pointed out that the current implementation of the Quantification Platform prototype has some limitations related to performance and tractability as well as result interpretation and validation. Also, not all aspects of the GARPUR RMAC are implemented. A main conclusion is that collaboration between TSOs and academics is still needed, especially regarding the control problem.

Rémy Clement, R&D Engineer at RTE, then introduced the work done related to the Asset Management problem, presenting the developed methods and proposed next steps. The work in GARPUR has targeted (long-term) asset management policy assessment, as well as (mid-term) outage scheduling assessment. The framework allows probabilistic assessment of the reliability and costs. A lifecycle based cost function is implemented, considering investment and logistics cost, operational costs and interruption costs. The framework allows monitoring of budget and workforce limitations, and provides output for both global and local levels. The data and model challenges are the same as for the other time-frames, and further work is required both on models and tuning of them, as well as data collection.

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Methods for the system development application, as well as lessons learnt from the corresponding pilot tests were presented by **Arnaud Vergnol**, a Power System Planner at Elia. The main challenge is to develop an adequate transmission system, considering economic efficiency. System development tools look far ahead in time; thus, the range of uncertainties becomes very large. The methodology has been tested by Elia in a near real-life pilot test. The objectives were to validate the proposed concept for screening the operating states and to compare the performance with the conventional approaches implemented in the same environment. The main recommendations for improvement of the GARPUR approach are: 1) To collect and share outage data, including the definition of a framework for collecting context dependent outage data and the adoption of the framework on a larger sampling base to improve quality, 2) To study a wide variety of contexts and clustering, this implies considering different expected future operating conditions and their evolution, as well as to adopt clustering methods to make it possible to assess a reasonable number of 'mini-scenarios'.

The final speaker of this session was **Simon Weizenegger**, Analyst at Statnett, presenting a system development study using a probabilistic approach. Norway is a country with long distances between cities, difficult terrain and harsh weather conditions. It is quite important to find the right balance between security of supply and infrastructure investments in order to save costs for society. Statnett sees in a probabilistic approach a transparent procedure to determine cost optimal solutions. The presented case study explored grid expansion and reinvestment alternatives for the Stavanger area and their impact on the security of supply after 2025. Advanced methods were used to determine interruption costs and costs of remedial actions. This required seasonal failure rates, which were improved with actual failure observations of considered grid elements by using a Bayesian adjustment. This information was utilised to evaluate contingency analysis for forecasted load flow scenarios. The expected power losses were expressed in costs by using a recognised Norwegian cost model, which differed between rural and urban consumers. The assessment revealed the total impact in terms of cost for society for each alternative. Thus a cheaper radial alternative could be recommended against a more reliable meshed grid expansion, because the higher reliability of the latter didn't justify the higher investment costs. This would lead to savings of 25%. Statnett is convinced that probabilistic approaches lead to better decisions and therefore is pursuing its efforts in this field.

Questions and answers

Following the five presentations there was a questions and answers session led by Irís Baldursdóttir, where the audience were invited to participate. Some highlights are following:

It was asked whether the additional cost of 130M€ in the Statnett case study would have been worth it since a more secure supply could have made the region more attractive to industry. This is already included in the study since all aspects, including reliability, are transferred to monetary terms. The analysis therefore shows that the increased reliability is not justifiable.

It was stressed the importance of having reliable data, and asked if the TSOs should start defining data as a critical asset, and apply asset management methodologies on the data as an asset. It was confirmed that data are critical assets and should be treated as such. To overcome the uncertainty caused by unreliable data it is suggested to apply sensitivity analysis, for instance, on failure rates and expected life time to quantify the value of the data in monetary terms.

It was asked if Landsnet plan to implement the RMAC on the Icelandic grid. It was explained that Landsnet is in a situation where transmission has increased, without investments keeping up. Therefore, sometimes the grid isn't N-1 secure and there is a wish for more accurate tools to assess the risk. The GARPUR methodology would also help explain why the limits are set as they are.

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It was asked if there might be a bigger risk with this methodology, simply because of its complexity and data requirements compared with N-1. It was replied that mainly the proposed methodology gives you more information. There is no need to take a bigger risk. The new method can be applied in parallel with N-1 to evaluate its performance.

It was commented on and confirmed the challenges to find reliable data and more specifically on the use by Landsnet of a tool to weight frequency and severity to rank the risks in their system. For instance, high probability low impact contingencies.
It was asked if this approach can be used by several TSOs together on a Pan-European level. It was replied that this will require sharing of information between the countries, and that some learning will have to be done while implementing since it probably will be too hard to specify all the elements that must be dealt with in advance.

It was asked how maintenance far ahead in time is considered in the system development problem, before maintenance plans are established. The goal of the work in GARPUR has rather been to determine the share of time when it is possible to perform maintenance for a given asset. This does not require a maintenance plan.

It was asked which data are already trusted in the RTE pilot, which needs to be developed, and if VoLL data is the one they trust the least. Regarding VoLL there are recommendations from CEER how to collect data. This is not the role of the TSO to figure out. The TSOs should rather focus on collecting failure rate data. It was also commented that the concept of VoLL is probably not perfect. For instance, it will not be applicable to an extreme event such as a blackout affecting entire Europe. For the RTE pilot, it was highlighted that the VoLL was not the key parameter to investigate. Instead, the quantification of the energy not supplied, as well as the quantification of the cost of a blackout, were the aspects to improve in priority.

2.4 Comparison of N-1 and the probabilistic approach

The session on comparison of N-1 and the probabilistic approach was introduced by **Frederik Geth**, Researcher at KU Leuven, who also had the first presentation. He gave some background on the need to be able to compare different reliability criteria, and explained the details of what the GARPUR Quantification Platform prototype can do. Still a lot of work is needed for the Quantification Platform prototype to be effectively used: more user-friendly, faster, a variety of new interfaces.

Pascal Tournebise, R&D Engineer at RTE, had the second presentation. He showed how the GARPUR Quantification Platform prototype had been tested on the Tavel-Realtor corridor in the south of France, a challenging area to prevent worst case scenarios. The objectives of this test were to highlight differences between N-1 reliability management criteria and the probabilistic GARPUR RMAC, to assess risk management in operation on a real example, and to highlight the challenges for further implementation by the TSOs. Cooperative work with KU Leuven has been very useful and made it possible to understand the behaviour of the Quantification Platform prototype. There are still several issues to consider, e.g. related to performance and tractability, and how to be able to use it on larger systems. However, the results are consistent with intuition, and it is shown that introduction of N-k (k>1) contingencies in the preventive problems should be economically weighted and justified, and that high preventive costs could be justified in case of difficult operational conditions.

Questions and answers
It was asked whether the Quantification Platform prototype would be able to do an analysis in real time. It was responded that it was made to compare the RMAC to the N-1 criterion, not for real time analyses.

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It was also commented on the findings, the intuition being that one can during normal operation neglect some less risky contingencies, whereas one during adverse situations will take into consideration more contingencies. It was responded that this is correct. Some tests were done where the RMAC was tuned to get the same reliability as the N-1 criterion. In this case the contingency list got shorter for good conditions and longer contingency lists for adverse situations.

2.5 Wrap-up: Further R&I challenges in reliability management

The session discussing further R&I challenges in reliability management was moderated by **Sonja van Renssen**, Freelance journalist. In his introduction to the panel debate **Louis Wehenkel,** Professor at University of Liege and Scientific Advisor of GARPUR, summarized what had been achieved in GARPUR so far, and listed some challenges to pursue in further work:

- Improve the physical and socio-economic models of power supply interruptions, and of the impact of costs and risk distribution among countries, regions, and stakeholders.
- Coping with the statistical challenge of exploiting existing data-sets and suitably enriching them, to improve models of uncertainties, of component health condition, and of corrective control failures.
- Addressing the computational challenges of risk-aware reliability assessment and control, towards a coherent suite of efficient and robust RMAC proxies and user-friendly software tools.

The panel to discuss this consisted of the following members:

- Thomas Trøtscher, Department leader, Data science, Statnett
- Patrick Panciatici, Scientific advisor, RTE
- Jonathan Sprooten, Head of Power System Planning, Elia
- Oddbjørn Gjerde, Research Manager and Coordinator of GARPUR, SINTEF
- Keith Bell, Professor, University of Strathclyde

The audience was asked which R&I topic should get the most attention in their point of view. 65 people responded in real-time, and the answers were as shown in Figure 1.

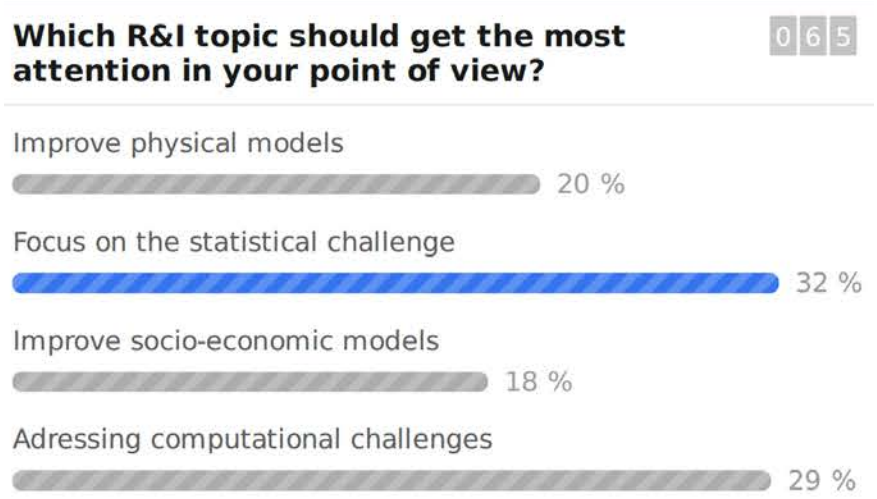

Figure 1: Poll question to the audience "Which R&I topic should get the most attention in your point of view?"

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The response from the audience was discussed in the panel. Statnett agreed that focus on the statistical challenge is important, and the need for good data. The TSOs should focus on implementing data collection systems to ensure that good quality data is available. RTE agreed on the need to improve data collection and data quality, and stressed the importance of the TSOs using the data in their operational process to make this work efficiently. On the computational challenges, machine learning need to be improved too.
Further, the importance of physical models was discussed. The accuracy of the models and the impact of this accuracy is a question. Also, the temporal aspect is considered to be quite a challenge.

A second poll question was given to the audience, do you think the methods and tools presented this day, will help to operate transmission systems more efficiently in the future? 49 people responded, and the answers were as shown in Figure 2.

Figure 2: Poll question to the audience "Do you think the methods and tools presented this day, will help to operate transmission systems more efficiently in future?"

The audience seemed to believe that the results from GARPUR will be helpful for the TSOs in the future. The panel debated this result, and within a TSO there are already many ongoing activities to manage risk at different levels. However, more transparency is needed and this can be provided by the GARPUR methodology. Further, it was discussed that challenges are different between the TSOs, this was also an aspect that needed careful consideration during the project. At the same time, there are similarities such as the lack of data – even if we are not able to tell which data we have, and the ageing infrastructure that need to be considered. As a final remark, it was suggested that the TSOs now introduce the concepts and methods gradually by developing the necessary models to solve specific methods. Pieces of the framework should be implemented rather than waiting for the opportunity to implement the holistic approach.

Some questions from the audience were also answered in this session, among other things the following were clarified:

- The GARPUR consortium does not currently intend to make the GQP (GARPUR Quantification Platform) public, more work need to be done first.
- DSOs have not been directly involved with the work of the GARPUR project, but some of the TSOs also operate distribution networks. It is expected that challenges related to data and the cross-impacts are and will be of the utmost importance
- If we stick to the N-1 criterion for the next 50 years it will not lead to any catastrophe, but we expect the TSOs to evolve and improve in this period.

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- Even if it may seem that each TSO has its own interpretation and implementation of the GARPUR framework, this basis is the same. The implementations are adapted to the different time horizons and problems under study.
- For testing the methodology in real life operation, a very first use could be to identify periods in time where the risk is at its lowest.

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3 DAY 2 HIGHLIGHTS

DAY 2 of the GARPUR Final Conference was moderated by **Sonja van Renssen**, Freelance journalist, and targeted especially **high-level decision makers** from both regulators and TSOs as well as policy makers from European organizations as for example ACER/CEER and ENTSO-E. This day allowed both GARPUR and other stakeholders to present and discuss their **general opinion on and challenges for implementation of a probabilistic approach for reliability management** on a strategic level.

Focus was on how new probabilistic reliability criteria as presented and proposed by GARPUR will have benefits for society and the challenges and benefits for TSOs, that goes with the implementation of a new reliability management approach. Each session contained both presentations from the GARPUR consortium, stating our recommendations and perspective, as well as presentations from other stakeholders (regulators and TSOs) where they brought forward their opinion towards a probabilistic approach followed by a debate between GARPUR and the stakeholders. The proposed transition roadmap towards a future with probabilistic reliability management was presented and discussed towards the end of the day.

3.1 Introduction to GARPUR and the probabilistic approach

The first session of day 2 was an introduction to GARPUR and a recap of day 1 by **Oddbjørn Gjerde**, Research Manager at SINTEF and Coordinator of GARPUR, and **Sonja van Renssen**, Freelance journalist.

In this presentation, Oddbjørn Gjerde explained what GARPUR is all about, and the fact that even if the N-1 criterion is the cornerstone of TSO reliability management, with the uncertainties of today it is not sufficient, and a better way to balance reliability and costs is needed. GARPUR has proposed a methodology allowing for assessing probability and consequences of failures, expressed as potential cost of power supply interruptions, thus making it possible to balance with investment and other operational costs. The methodology is adapted for and tested in practical use, with the aim to maximize social welfare.

The GARPUR approach has a technical part and a socio-economic part – and they are joined together through the project. The methodology relies on four main components; a socio-economic objective, a reliability target, a discarding principle and a relaxation principle.

One part of the proposed reliability management is to optimize the **socio-economic costs** and benefits for a given activity. In real-time operation, for example, the economic objective would be to minimize the total sum of different types of costs, including the costs of preventive and corrective measures and the costs incurred by end-users in case of a power supply interruption. Taking decisions optimising the socio-economic objective may cause unacceptable system performance, for instance, too high probability that interruptions may occur. Therefore, a range of unacceptable situations are identified, together with the probability to avoid them. This will be the **reliability target**. For example, to ensure with 99.9% probability that no power supply interruption above 100 MW should occur.

In practice, strictly applying the two previous components are not feasible, as one could not consider all possible events. Therefore, the **discarding principle** is introduced. It allows to ignore, dynamically, events with risk below a certain threshold. For example, one could choose to consider only events with an expected interruption cost above 100 k€. The last component is the **relaxation principle**: It is possible that when a decision is to be made, there are no available options fulfilling the previous requirements.

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Then the threshold for discarding can be progressively increased until a solution is found. In practice, this would mean ignoring the events that relatively have the lowest risk.
The main advantage of the framework is that it enables better informed decisions for the TSOs. The value of reliability can be calculated and compared to the investment and/ or operation costs, and cost savings for society can be reached.

The GARPUR vision is "**An adoption of probabilistic reliability management by all stakeholders dealing with electric power systems reliability management, from experts in the TSO organizations who have the practical responsibility to ensure the security of electricity supply, to the persons in charge at regulators and governments whose responsibility is to ensure the electric power system performs for the benefit of all parts of society.**"

3.2 Benefits for society and possible barriers for implementation from a regulatory perspective

The second session of day 2 was introduced by **Gerd Kjølle**, Chief Scientist at SINTEF, with the theme "Socio-economic approach in GARPUR and examples for the impact of GARPUR". She explained how the optimal balance between reliability and cost is a trade-off between the benefit of increasing the reliability level, versus the costs of providing it. Theoretically it is possible to increase the reliability to nearly 100%, yielding unfeasible grid costs. A higher reliability level will lead to decreased costs of power supply interruptions. The optimum level is found where the sum of the total socio-economic costs are at the minimum or where the marginal costs are equal. A higher reliability level than the optimum, would give too high grid costs compared to the reduction in the interruption costs. This means over-investment (over-spending). Similarly, a lower reliability level than the calculated optimum level, would represent under-investment (under-spending).

The N-1 criterion isn't necessarily socio-economic optimal. In some situations, it would yield a too low reliability level in socio-economic terms, and in other situations a too high level. The benefit of the probabilistic approach is that it enables considering the socio-economic costs, here the TSO costs and expected interruption costs, and in principle achieve an optimal level of reliability.

To be able to deal with this trade-off between the reliability level and the costs in the reliability management in the various time horizons, the GARPUR methodology incorporates the concept of **customer interruption costs** (here used synonymously as the Value of Lost Load, VoLL). The interruption costs will depend on different characteristics, such as consumer type and location of the consumer, the time of interruption and duration of interruption, and if the interruption was notified in advance or not. It also depends on the perceived level of reliability of supply.

In the early phase of GARPUR, state of the art was studied and the current practices regarding reliability management in Europe were examined. As a part of that, important drivers and barriers for new reliability standards were identified. The question was raised **whether regulation was a driver or a barrier**?

It was found that the regulation was considered both as a driver for and a barrier against probabilistic (and socio-economic) reliability management by the different TSOs/ in different countries. The Norwegian quality of supply regulation which is based on socio-economic principles incorporating customer interruption costs, was one example with regulation as a driver. This regulation gives incentives to minimize the total socio-economic costs. The other example with regulation as a driver was

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the Dutch regulation, where the rule states that the grid is designed and operated in such a way that a single interruption has no impact. However, the rule may be ignored if the costs exceed the benefits. Finding the right balance between the opposing objectives of reliability of supply and costs, is the role of the regulator, based on society's preferences.

Currently, the regulatory framework organizing and incentivizing the power sector is in general not fitted to probabilistic reliability management. Incentives, remunerations, roles and responsibilities are defined to ultimately ensure that the power system is N-1 secured. Therefore, a next step should be to expand the regulation to consider the probability of failure and risk associated with the N-1 faults that TSO's are already assessing and to encourage the use of the new reliability targets and socio-economic evaluation criteria. The remuneration mechanisms of TSOs should also be adapted to incentivize them to implement the new approach in the most efficient way. For this decision-making, the regulators need information and a better understanding of the benefits and the socioeconomic consequences of the probabilistic reliability management approach compared to the existing reliability management. Making use of the GARPUR approach also requires **available and good quality data**.

A panel was established to discuss "What is the willingness of the regulators to embrace the probabilistic approach based on socio-economic principles?", consisting of the following members:

- Martin Queen, Senior Technical Adviser, Ofgem, UK
- Vegard Willumsen, Head of Section Power Systems, NVE, Norway,
- Jakub Fijalakowski, Senior Adviser/ Co-chair of ACER's System Operation and Grid Connection Task Force, E-control, Austria
- Alain Marien, Chief Adviser, CREG, Belgium
- Gerd Kjølle, Chief Scientist, SINTEF, Norway

The first question raised to the panel was "How do you regulate the TSO in your country related to reliability management?"

In the **UK,** mainly deterministic N-1 is used. The regulation allows for some principles (severe weather, consequences of severe weather) and certain aspects of GARPUR. On asset management, the different assets are prioritized based on criticality. It is important to take a holistic aspect.

The socio-economic objective is already implemented in the regulation of grid companies in **Norway**. The regulator has a strong believe that incentivizing the company is the best way to achieve it. The N-1 criterion is nice and easy, but if the regulator is asked for permission to build a new line, N-1 is not the deciding criteria and socio-economic aspects have to be considered. It is regarded as more important to do smart investments than to focus on N-1 criteria. And maybe N-2 is the socio-economic optimum sometimes.

In **Austria,** the operation guidebook is applied, using the N-1 criteria. However, they foresee that a probabilistic approach is the future. A transition may already be ongoing: a probabilistic approach could become mandatory within the European regulation.

There are no specific requests to use anything beyond the N-1 rules in **Belgium**. However, some arrangements incentivize indirectly. Application of the Dynamic line rating should have an important influence on the capacity of day ahead market. Areas where GARPUR can be used has been identified as transmission planning and for the assessment of the Flow Reliability Margin.

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The audience was asked if regulators should aim at a certain level of reliability or for a pure socio-economic approach. 55 people responded, and the answers were as shown in Figure 3.

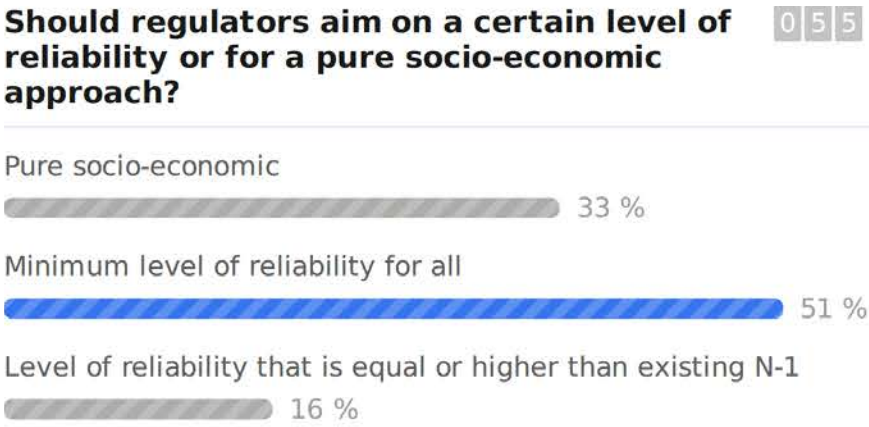

Figure 3: Poll question to the audience "Should regulators aim on a certain level of reliability or for a pure socio-economic approach? "

The result was discussed in the panel. There seemed to be consensus in the panel that there should be a mix of a socio-economic approach and certain requirements to the minimum level of reliability. But the minimum level of reliability may need to be differentiated, and also harmonised between the countries in Europe.

Some questions from the audience were answered, among other things the following were clarified:

- There is no harmonised methodology to compare TSOs performance with respect to reliability, but SAIDI[1] and SAIFI[2] is compared.
- To define value of lost load (VoLL) surveys is the most common methodology. CEER has defined guidelines on good practices how to carry out such surveys.

The audience was asked how important it is to change regulation to be able to start with the implementation of the proposed approach for reliability management. 53 people responded, and the answers were as shown in Figure 4.

The results indicate that already the existing regulation have room for a probabilistic approach, at least to a certain extent. This was also confirmed by the regulators in the panel. The importance of good data was highlighted once again.

[1] System Average Interruption Duration Index: SAIDI is the average outage duration for each customer served
[2] System Average Interruption Frequency Index: SAIFI is the average number of interruptions that a customer would experience

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Figure 4: Poll question to the audience "How important is it to change regulation to be able to start with the implementation of the proposed approach for reliability management? "

3.3 Challenges and benefits for probabilistic reliability management for TSOs

Session three of day 2 was introduced by **Irís Baldursdóttir**, Vice President at Landsnet. The theme of the session was challenges and benefits for probabilistic reliability management for TSOs. In her speech, Irís talked about experience, results and recommendations for TSOs. She explained the picture with the different time frames and tasks as seen from a TSO, and how the different pilot tests of GARPUR fit in it. The pilot tests did not allow to cover everything. Examples were given how GARPUR can be applied on the transmission system in the different time frames, system development, maintenance planning and real-time operation.

The lessons learnt from GARPUR was related to the different time frames, and benefits and barriers explained:

In **system development**, clustering methods have been proposed for future operating states, which are found to be useful and tractable in practice. With the proposed method, the operator can get a view of the maintainability of each asset separately. The conditions under which a given asset can be taken on outage or not can be identified. The tests identified that the maintenance of some elements was weather dependent (the transformers could not be maintained in case of strong wind production). Further, it was shown by tests that optimal social outcomes can be achieved by comparing different investment alternatives in terms of risk and investment cost. Altogether, significant socio-economic savings can be achieved.

On the barriers side, it was highlighted that size of clusters varies over time, resulting in inconsistent computation times, and that resources and development effort for using a probabilistic approach must be available.

In **asset management**, the framework can assist in solving issues with ageing infrastructure. It can quantify impact of maintenance policies and outage schedules on operational security with help of proxies, and enables to better prioritize the resources.

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Identified barriers are that significant computational resources will be required to solve asset management studies. And it must also be mentioned that the modelling of the degradation process of the assets is challenging.

In **real-time operation,** a main, and important, experience is that the pilot test results match intuition of experienced operators and identified sensitivities are in line with expectations. The framework is found to be flexible enough to allow for various acceptability constraints (e.g. the ENTSO-E incident classification scale). It provides a trade-off between preventive and corrective control, and it can capture impact of exogenous threats on reliability.

Possible barriers against using the GARPUR methodology in real-time operation is that the indicators do not provide insight into why the risk is at a certain value at any point in time. They still need to be developed further to be a clear support for the operator in the control room. The residual risk need to be calculated more accurately, the speed of state-of-the-art system response models limit scalability, and there is a need for more detailed models of system restoration.

For the TSOs to move forward with the probabilistic methodology the following aspects and actions are highlighted:

- Guidelines for new data collection and sharing should be established, to overcome issues with data sparsity.
- TSOs need to coordinate the reliability management between them, this is a complicated task even with only two TSOs.
- It is necessary to continuously evaluate results to show the value of migrating to probabilistic practices.
- Further pilot testing of the methods applied to real-world systems.

To discuss the "Overall complexity and the need for a holistic view on the different time horizons", a panel was set up consisting of the following:

- Yannick Jacquemart, Director of Research and Development, RTE, France
- Håkon Borgen, Executive Vice President, Technology and Development, Statnett, Norway
- Kristof Sleurs, Head of Grid development, Elia, Belgium
- Irís Baldursdóttir, Vice President, Landsnet, Iceland

The initial question raised to the panel was "How do you approach reliability management, and are you planning to apply probabilistic approaches?"

At **Elia**, several projects are ongoing to move towards probabilistic approaches. Among other they are at the beginning of quantifying various things such as expected load curtailment, condition based maintenance and dynamic reserve dimensioning. Cooperation and communication between the different departments is very important in this context. A specific result of GARPUR that Elia will consider implementing in their operations is the concept of clustering operating states.

RTE has a long history of using probabilistic approaches, mostly related to power system planning. Probabilistic approaches will open for smart systems operated closer to their margins, rather than investing more in the bulk system. A gradual move towards probabilistic approaches is expected by RTE. At the same time, they don't feel that the regulator incentivizes them to make this move.

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Statnett also has experience with probabilistic approaches and socio-economic principles, operating closer to the margins. Parts of Statnett's grid is not N-1 secure during parts of the year (operating states), and have not been reinforced due to lack of socio-economic surplus. To better estimate the risk Statnett has put a big effort into data collection.

Some questions from the audience were discussed and clarified:

- There is a **dilemma regarding data**; while GARPUR suffers from lack of data, N-1 ignores the data entirely. This is not an argument for N-1; we should consider the data that we have.
- Even if the pilot tests confirm the intuition of the operators and provide the same results, there is an **added value of GARPUR**: The system is so complex that the system operators cannot have a complete overview. This will become even more challenging in the future with the increased variability. Decision support is needed.

The audience was asked where they see the main challenges and barriers for the application of the new approach in the TSO. 59 people responded, and the answers were as shown in Figure 5.

Figure 5: Poll question to the audience "Where do you see the main challenge and barriers for the application of the new approach in the TSO? "

Based on the response from the audience, confidence in the new approach is considered to be the main challenge. **Elia** commented that confidence in the approach is required both from the TSOs and from the outside world, and transparency is a keyword. **Statnett** commented that implementing this approach would require well performing teams within the company, and that the management has faith in the new decision-making process to get the holistic view and focus. **RTE** agreed to this, this will be a decision chain that must be fully integrated. And concerning the debate on data and tools; the more complex the data are, the more complex is decision-making.

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Further questions from the audience that were discussed and clarified:

- The methodology is already more or less implemented for some time horizons at some TSOs, e.g. Landsnet have come a long way in system operation. It is difficult to **say whether the methodology is fully implemented within five years or not**, but the first steps can be made already today.
- **Availability of tools** is a central point. We do not foresee that there will be one new tool as a result of GARPUR, rather a set of various tools that will be progressively developed and implemented.

The audience was asked where such a probabilistic approach to reliability management should be implemented first. 60 people responded, and the answers were as shown in Figure 6.

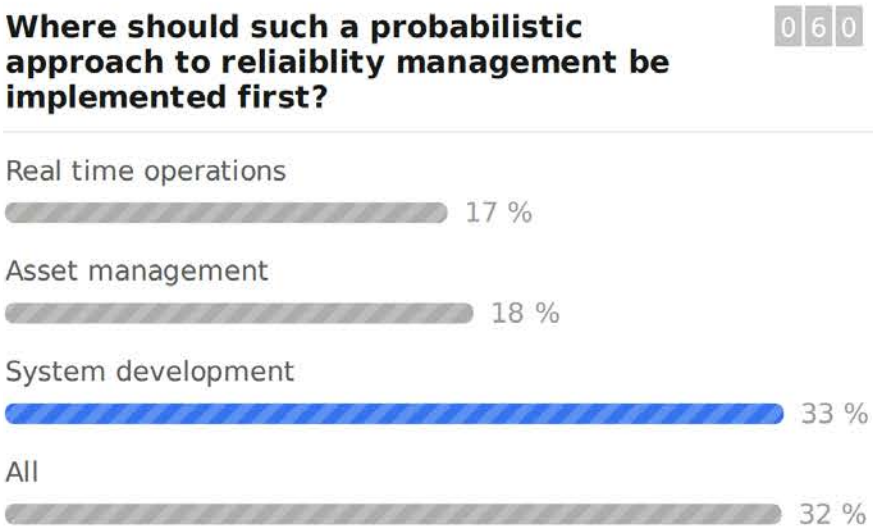

Figure 6: Poll question to the audience "Where should such a probabilistic approach to reliability management be implemented first? "

The response shows that the view on this is split. **RTE** commented that this is a global framework, covering all time horizons, and that if you implement it in system development and not in real time operations, then what you simulate in system development is not actually simulating your system. **Elia** supported this view; it is crucial that if one does this in planning it also should be done in real time. One cannot tell the operators to be N-1 secure with a grid that was not designed to be N-1. **Statnett** believed it doesn't matter where one starts, but should end up with implementing it for all time horizons. **Landsnet** commented that a parallel approach should be preferred.

Further questions from the audience that were discussed and clarified:

- A misunderstanding had appeared that the GARPUR approach could not be used for real-time or close to real-time operations. This is not correct, as the **GARPUR approach can be applied to all time horizons**, system development, asset management and real-time operations.
- The panel agrees that the **TSOs will have to coordinate**. Harmonization and transparency will be crucial. This **also applies to the data collection and exchange**, to provide a better basis for calculations and simulations. At the same time, it may be ambitious to have a full harmonization, there may be needs for individual or regional adaptations, e.g. adequacy is dealt with differently in a hydro dominated system compared with a gas and coal based system.

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- To the question **if the regulators will incentivize for the move** towards a new approach, it seems more like that they will keep the door open for it. Anyway, the panel agreed that the change will not happen overnight, the transition will happen incrementally, and N-1 and probabilistic criteria will coexist in the interconnected European grid.
- The panel all agreed that **the benefits with the new approach will be worth the investments** related to it.

3.4 Transition roadmap towards probabilistic reliability management

The final session was introduced by **Manoël Rekinger**, Innovation project leader at Elia. The topic of the session was the transition roadmap towards probabilistic reliability management. In his speech, Manoël talked about how the GARPUR story can continue, to make Europe move forward. He started with reminding on the introduction to the previous session, and how TSOs can move forward through data collection and sharing, coordination of the reliability management between them, evaluation of results and further pilot testing. In addition, there is a need for a common vision and roadmap to fully harvest benefits for Europe.

The vision of the GARPUR project is an **adoption of probabilistic reliability management by all stakeholders dealing with electric power systems reliability management**: TSOs who ensure security of supply, regulators and governments who ensure that the electric power system performs for the benefit of all parts of society, research organisations who think out the next state of the art algorithms and methodologies, and technology providers who provide industrial grade software and ICT infrastructures.

There are challenges on the way to this vision that will need to be overcome: The regulatory framework is not fitted to probabilistic Reliability Management, lack of data and information gathering and sharing, lack of risk-based mindset and confidence in probabilistic Reliability Management, lack of tools and competence in the industry. But actions can be taken to overcome these challenges, as described in the transition roadmap, with **four main building blocks**: Regulation and socio-economic considerations, Data and models of uncertainties, Methodology, algorithms and software, and Testing and implementation.

On **Regulation and socio-economic considerations**, anticipating the socio-economic impact of moving towards a probabilistic reliability management approach, regulators need information and a better understanding of the benefits and the socio-economic consequences of the probabilistic reliability management approach compared to the existing reliability management. Needs for changing the regulation is also identified, the probability of failure and risk associated with the N-1 faults must be considered and remuneration mechanisms of TSOs should be adapted to incentivize implementation of new approach. Also, coordination of the reliability management practices in Europe is required.

The block **Data collection and models of uncertainties** implies enhancing the quality and availability of data and improve related models. Firstly, collecting key data is crucial, such as failure data to estimate the probability of contingencies and restoration rates and outage times of contingencies to estimate the consequences, and interruption cost data to estimate the expected socio-economic costs of the consequences in terms of power supply interruptions. Data that need specific improvements are VoLL, degradation processes, maintenance impact and corrective control failures. Based on the data, improved models can be developed. It is recommended to implement common guidelines to ensure the collection of data, maintain the databases, and the inferred models, and share them among the different stakeholders concerned.

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Regarding **Reliability management methodology, algorithms and software**, there is no doubt that a probabilistic reliability management approach is significantly more complex from the computational point of view, compared to a deterministic N-1 based reliability management. Therefore, further development of methods is needed: proxies, SCOPF and filtering. A next generation of industrial grade software and tools also needs to be developed, with the necessary robustness, efficiency and availability.

On **Testing and implementation**, it is our clear view that pilot scale testing of the new methods and approaches are an important next step to change the mind-set and to increase the trust in probabilistic reliability management at the same time. More testing at TSOs to gain further confidence and acceptance, and to develop know-how, is required. This should be supported by an Open-science approach to power systems reliability assessment, by sharing data and software among industry and the research community.

The final questions from Manoël on how to come from GARPUR results to practice:

- How to develop a regulation fit for probabilistic reliability management?
- How to ensure data collection and sharing among the different actors and countries?
- How to increase the interaction between TSOs, academics and technology providers?
- Not putting the cart before the horse, how to accompany TSOs and regulators in this desirable evolution?

The very first step in solving this is by starting to put the right people around a table.

To debate "Fostering the probabilistic reliability management – discussion with affected stakeholders", a panel was set up consisting of the following members:

- Louis Wehenkel, Professor at University of Liege and Scientific Advisor of GARPUR
- Sonya Twohig, Head of System Operation, ENTSO-E
- Karel Vinkler, Director of Strategy department, CEPS
- Arne Ellerbrock, Application Engineer, DIgSILENT
- Matti Supponen, Policy Co-ordinator, European Commission

The first question of the debate was handed to Sonya Twohig from ENTSO-E**,** asking **if probabilistic approaches is already a topic** there. It was responded that this is a topic of importance for ENTSO-E. E.g. related to analysing causes of major interruptions, guidelines on security etc. ENTSO-E believe they have a good structure to move further with probabilistic approaches. It may be relevant to implement regional initiatives through the regional security centres. It is not believed that regulatory changes are required to move on with this work.

Karel Vinkler, from CEPS, was asked **how ready he thinks TSOs are to implement the GARPUR approach**. In his response, he pointed out that a new adequacy assessment based on a probabilistic approach started already three years ago. The TSOs will need a common method, and preferably a common tool, for collecting data. The risk indicators are already well defined and useful for long- and mid-term, but there is a need for further development of short-term risk indicators.

Arne Ellerbrock, from DIgSILENT, was asked about his view on **when software will be available** implementing probabilistic methods. He highlighted that this will be required as the grid becomes more and more complex and operated closer to the limit. We have more controllability and active devices, like different power electronics, HVDC, TSC and special protection systems. But so far it has not been defined how to use them, or how to model and account for them in simulations. Probabilistic load flow will be

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part of the next release from DIgSILENT, but considering the delay from research to market implementation it will take several years before the GARPUR methodology is sufficiently developed and implemented in commercial software.

The next question was for Louis Wehenkel, from University of Liege, on what he sees as **the next big topic for research to focus on** to enable the GARPUR methodology. He responded that it is important for the research community to produce their research and results in such a way that they are more reusable for other stakeholders. This could speed up the transfer from research to industry. Himself he would like to apply machine learning techniques to this kind of problems, using actual data from various TSOs.

Matti Supponen, from the EC, was asked **how he thinks the EU can support such a probabilistic approach**. He replied that the EC will probably see many opportunities, and that there will be a list of things that they can support. This could be in the form of regulations and network codes. He warned that the timeline is rather long, if a process is started now it could be implemented in 2025.

The audience was asked who should take the main lead to implement probabilistic reliability management. 62 people responded, and the answers were as shown in Figure 7.

From the response, it seems quite clear that the audience believes that the main responsibility lays with the TSOs and ENTSO-E (who are also the TSOs). Karel Vinkler commented that the results reflect the reality. Even if the main responsibility is with the single TSO, ENTSO-E is the key to enable to discuss common issues on methodology or risk assessment, especially between neighbouring TSOs. The question on Regional Coordination Centres or Regional Operational Centres is tricky, it makes sense to formulate some tasks on risk preparedness on operations with probabilistic methods. But mid-/long-term planning should be based on more volunteering approaches, and cooperation could be preferable.

Sonya Twohig confirmed that ENTSO-E could have a role in such a development; the level requires that it should be within ENTSO-E. Each region has its own challenges on interconnection on generation. The risks are individualistic and we have regional structure that can assess that, an appropriate tooling could come in addition.

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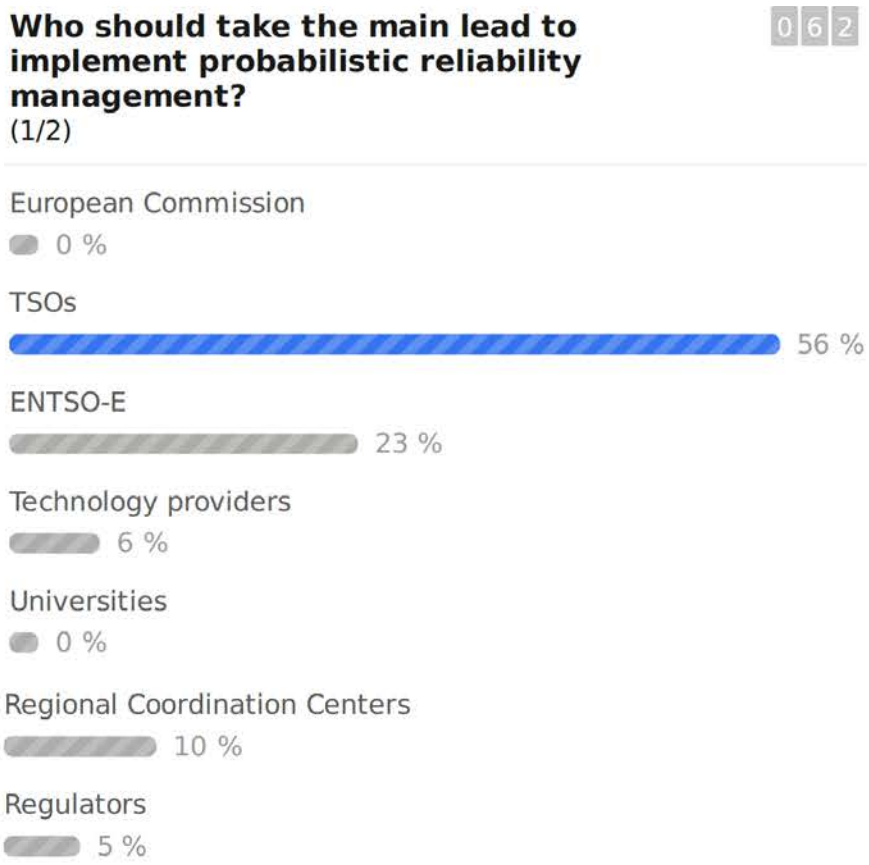

Figure 7: Poll question to the audience "Who should take the main lead to implement probabilistic reliability management? "

The audience was then asked which future work must be done. 57 people responded, and the answers were as shown in Figure 8. The response is somewhat spread, between testing in TSOs, implementation and development of new tools, and more research cooperation between TSOs and universities.

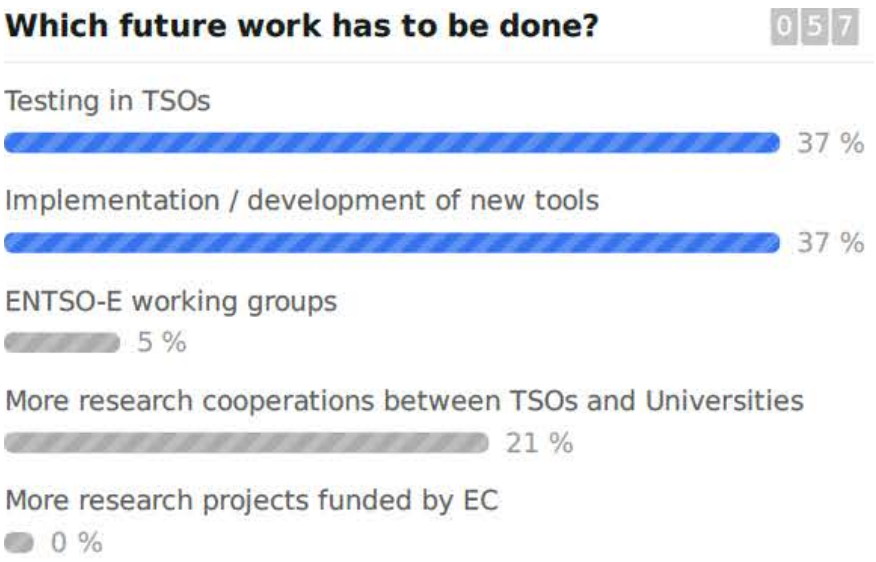

Figure 8: Poll question to the audience "Which future work has to be done? "

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In the discussion, the importance of testing was highlighted. Data is also an issue, both availability and confidentiality. A win-win situation could be if providers implement tools and a standard format for reliability data. A confidentiality agreement could be signed to exchange data.

RTE were clear that they want to move forward with the GARPUR methodology and continue the testing on some remaining topics. They would like to set up tools like open source to help the community to progress and keep momentum. Huge work is already done, and now it is time to create something on the top. This was supported by CEPS as a good recommendation, they are also prepared for testing, and can prepare their own tools. But the methodologies and experience should be spread in and between the TSOs, and here some governance and cooperation is needed and recommended.

Further, it was discussed whether moving forward will require a new type of hybrid power system and software engineers. It was commented that there is a need for data science, and it is also important to understand the physics of the system. This may lead to a need for longer training than for the traditional engineers. The discussion on cyber security was also touched upon, and ENTSO-E informed that they will launch their strategy on cyber security and risk preparedness, which will clearly call for competence on data science within the TSOs, but also on risk management.
Finally, the regulators were asked to comment how to move forward. From the discussion, it can be extracted that the regulators believe that new regulations or network codes are not needed, but some adjustments may be required.

In the final poll, the audience was asked if they think all stakeholders are ready to start the implementation of probabilistic reliability management. 49 people responded, and the answers were as shown in Figure 9.

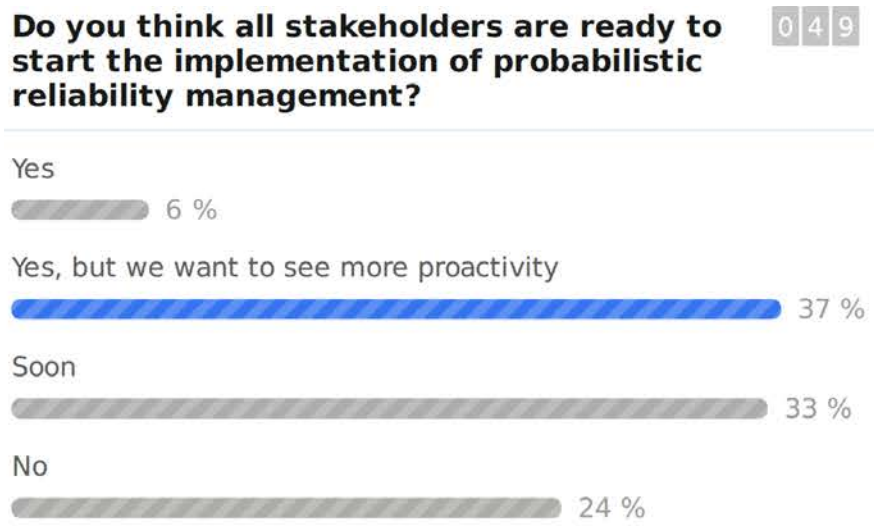

Figure 9: Poll question to the audience "Do you think all stakeholders are ready to start the implementation of probabilistic reliability management?"

The response shows that about the ¾ of the audience believe that all stakeholders are ready to start the implementation of probabilistic reliability management already now, or in the near future.

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3.5 Closing words

In his Closing words, **Patrick van Hove**, from the European Commission, expressed his thanks to the GARPUR consortium, and to the audience, which is large taken the type of conference into account.

Further he commented that he was very happy about the results. The final proof yet remains, as this requires further pilot testing and thereafter implementation by the TSOs. This is also in line with the roadmap – where six out of twelve actions are for TSOs. Concerning regulatory aspects, it has been indicated that actions for regulators are only deemed to be necessary in the future, so that this would not hinder early development and deployment of project results. Lack of data may be a challenge, and he encouraged to make as much of the data as possible open – as this may engage more researcher to work with the problem. The pilot tests seem to already have started a change in the mindset of the power system operators, change will continue, and there is hope that industry will take on the work with industrialized tools.

Finally, he encouraged the consortium to look for opportunities in H2020 workplan 2018-2010, and also in FP9. And as he will use opportunities to promote the project and its results, the TSOs should promote the project and results in their organisations.

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APPENDIX I: FINAL CONFERENCE PROGRAMME

10:00 Welcome and introduction

Welcome
Petter Støa, Research Director, SINTEF

Introductory speach
Patrick Van Hove, Project Officer for GARPUR, European Commission

Overview of the project
Oddbjørn Gjerde, Research Manager and Coordinator of GARPUR, SINTEF

10:45 Probabilistic framework for reliability management

Development of new reliability criteria
Efthymios Karangelos, Postdoctoral Research Associate, University of Liege

Socio-economic assessment of reliability criteria
Fridrik Már Baldursson, Professor, Reykjavik University

Q/A

12:15 LUNCH

13:45 Application in TSO's reliability management tasks

System Operation: Methods and lessons learnt from pilot tests
Irís Baldursdóttir, Vice President, Landsnet

System Operation: Key results, migrations & validation
Pascal Tournebise, R&D Engineer, RTE

Asset Management: Methods and next steps
Rémy Clement, R&D Engineer, RTE

System Development: Methods and lessons learnt from pilot tests
Arnaud Vergnol, Power System Planner, Elia

Benefits of a probabilisitc approach in a real system development study
Simon Weizenegger, Analyst, Statnett

Q/A

15:45 COFFEE

16:15 Comparison of N-1 and the probabilistic approach

Presentation of the GARPUR Quantification Platform
Frederik Geth, Researher, KU Leuven

Testing the functionality of the GQP
Pascal Tournebise, R&D Engineer, RTE

Q/A

17:15 Wrap-up: Further R&I challenges in reliability management

Introduction
Louis Wehenkel, Professor and Scientific Advisor of GARPUR, University of Liege

Panel: Filling the scientific and technical gap

- Thomas Trøtscher, Department leader Data science, Statnett
- Patrick Panciatici, Scientific advisor, RTE
- Jonathan Sprooten, Head of Power System Planning, Elia
- Oddbjørn Gjerde, Research Manager and Coordinator of GARPUR, SINTEF
- Keith Bell, Professor, University of Strathclyde

18:00 End of Day 1

19:00 DINNER

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Programme Day 2

Wednesday 18 October

Moderated by Sonja van Renssen, Freelance

09:00 Introduction to GARPUR and the probabilistic approach

Introduction to GARPUR and the probabilistic approach

Oddbjørn Gjerde, Research Manager and Coordinator of GARPUR, SINTEF
and Sonja van Renssen, Freelance

09:20 Benefits for society and possible barriers for implementation from a regulatory perspective

Socio-economic approach in GARPUR and examples for the impact of GARPUR approach

Gerd Kjølle, Chief Scientist, SINTEF / GARPUR

Panel: What is the willingness of the regulators to embrace the probabilistic approach based on socio-economic principles?

- Martin Queen, Senior Technical Adviser, Ofgem, United Kingdom
- Vegard Willumsen, Head of Section Power Systems, NVE, Norway
- Jakub Fijałkowski, Senior Adviser / Co-chair of ACER's System Operation and Grid Connection Task Force, E-control, Austria
- Alain Marien, Chief Adviser, CREG, Belgium

10:20 COFFEE

10:45 Challenges and benefits of probabilistic reliability management for TSOs

Experience, results and recommendations for TSOs

Irís Baldursdóttir, Vice President,
Landsnet / GARPUR

Panel: Overall complexity and the need for a holistic view on the different time horizons

- Yannick Jacquemart, Director of Research and Development, RTE
- Håkon Borgen, Executive Vice President Technology and Development, Statnett
- Kristof Sleurs, Head of Grid development, Elia

12:00 LUNCH

13:30 Transition roadmap towards probabilistic reliability management

A transition roadmap: How can Europe move forward?

Manoël Rekinger, Innovation project leader,
Elia / GARPUR

Panel: Fostering the probabilistic reliability management - discussion with affected stakeholders

- Louis Wehenkel, Professor and Scientific Advisor of GARPUR, University of Liege / GARPUR
- Sonya Twohig, Head of System Operation, ENTSO-E
- Karel Vinkler, Director of Strategy department, CEPS
- Arne Ellerbrock, Application Engineer, DIgSILENT
- Matti Supponen, Policy Co-Ordinator, European Commission

Closing words

Patrick Van Hove, Project Officer for GARPUR, European Commission

15:00 End of GARPUR Final Conference

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APPENDIX II: FINAL CONFERENCE – PARTICIPANTS

Name	Affiliation	Country
Jacques WARICHET	AcuGrid	Belgium
Hendrik NATEMEYER	Amprion	Germany
Ralph PFEIFFER	Amprion	Germany
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APPENDIX III: QUESTIONS RAISED BY THE AUDIENCE

In the following the questions received from the audience by SLI.DO are listed session by session.

Day 1

Wrap-up: Further R&I challenges in reliability management

- Do you intend to make GQP public?
- How does the GARPUR approach feed into asset specifications especially overhead lines? Surely there would be a feedback loop to achieve the optimal spec?
- Are there representatives of DSOs here today? The challenge related to data and the cross-impacts are and will be of the utmost importance
- How can GARPUR be adapted for multiple regions/TSOs?
- How is the DSO reliability considered in the probabilistic Garpur methods?
- If TSOs are stubborn and stick to the N-1 principle over the next 50 years, do you foresee some catastrophe?
- It seems that each TSO has their own interpretation and implementation of the reliability study. There is a consensus on the use of the methodology among TSOs?
- Do regulators want to establish a minimum level of reliability?
- Humans are not really good in making decisions based on probabilistic data. The challenge is aimed to model the decision processes
- Should machine learning be a new focus for power system engineers? Do we need hybrids in future? And is this lack of competence a problem at the TSOs currently?
- Up to which degree, black box models will be accepted in real world applications
- Data is an issue but it has been extensively collected over the last 50 years at least. Which data is the most challenging and which impact the most?
- In which topics should TSOs work together with research organizations? Where do they can already test the probabilistic approach without more research projects?
- The choice of the reliability level and the cost trade-off is a societal decision. How do want to engage the general public in this complex issue?
- It sounds like that many TSOs do not find it interesting to reduce the reliability (lower than N-1) even if it turns out to be more socio-economic beneficial. Why?
- Should TSO remuneration schemes change to create a need to reassess reliability?
- Do you know if TSOs outside of the consortium are also considering GARPUR-like ideas?

Day 2

Benefits for society and possible barriers for implementation from a regulatory perspective

- As an electricity consumer, how much (in euro/MWh) would be your personal Value of Lost Load?
- What proposals would anyone have for how to improve on 'willingness to pay' or 'willingness to accept' survey methods for estimating VOLL?
- Is a cultural change in regulators needed to implement the new approach?
- How do you regulators compare the performance your national TSOs with respect to reliability with other European TSOs? Is there any harmonized methodology?

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- What are the regulators thoughts on how the value of lost load should be quantified? Do you think we are able to quantify it at all?
- It is said that GARPUR suffers from a lack of data, whilst N-1 ignores the data entirely. Why is this argued as a benefit of the N-1 approach?
- With the increase of monitoring devices and ICT support, do you think that reliability of the ICT system itself will become an issue?
- Who will approve national reliability level and what will be coherence between nationals and pan-European level of reliability?
- Should we individualize reliability levels using reliability-based tariffs?
- It is not nice to refer to common sense if we are about to introduce a sophisticated, IT reliant solution.
- How is it possible to justify an investment without a robust VOLL?
- Can theoretical VoLL values be relied on if customers are not in reality exposed to paying those costs?

Challenges and benefits of probabilistic reliability management for TSOs

- When will a GARPUR Software be available on the market?
- Was the trek Iris mentioned the one from Landmanalogar to Skogar? If so, just a testify that it is indeed a really memorable route! Go to Iceland!
- Do you see a need for coordination between the TSOs for the implementation? On the principles? On the desired level of reliability?
- Are greenhouse emission costs considered in the GARPUR socioeconomic cost calculations?
- If the results from GARPUR are the same as operator intuition, what extra information does the operators get from GARPUR?
- TSOs do already use corrective actions. In principle, more use of them should deliver similar reliability as now but at lower cost. Is that storing up trouble?
- Do you think that the eventual lack of computing power could be a barrier to the adoption of GARPUR methodologies?
- How do you guard against transferring the risks to other TSOs and relying on them to solve 'your' issues at their expense?
- Tools, processes and people can be achieved. Getting accurate data is very hard - based on many years of experience. As with VOLL, GARPUR won't work without it
- First steps are taken in terms of probabilistic reliability assessment, but on which time horizon do you see the Garpur SCOPF be applied in reliability control?
- Don't we need substantially different ways of security assessment and probabilistic data collection between transmission and distribution system?

Transition roadmap towards probabilistic reliability management

- Is Garpur a vision just in Europe or are other countries and regions in the world going on the same path?
- Some TSOs already do a lot to collect much of the data a GARPUR approach needs; others do not. Is it reasonable for the latter to be given more money to do it?

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- Who exactly are the right people? Where is the table?
- Do we have after-GARPUR project for mass acceptance? Or TSOs will do it for themselves?
- Data, digitization and complex methods.... Do we need new hybrid data science/power system engineers in near future? How will TSOs and universities push this?
- We have heard about several challenges in these two days; data quality, tool performance, regulation, new operational practices. But what would be the next step?
- We seem clear that TSOs /should/ take the main lead to implement GARPUR-style methods. Are we each of us confident that our home TSOs actually will continue on that way?
- The R&D project comes to an end. What initiative or framework can the EC propose for this community to continue meeting and exchanging?

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