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

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Duration: 4 years

D8.3
Results from near real-life pilot testing

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Organisation name of lead beneficiary for this deliverable:
Landsnet hf.

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

General Summary

The GARPUR Project proposes a new family of reliability management approaches and criteria, for use in various contexts of Transmission System planning asset management, and operation. To validate the practicality of incorporating these methods into real-world operation, several near real-life pilot tests and case studies are performed. These tests primarily investigate the feasibility of implementing the new criteria in practice, in terms of data availability and model tractability. Further investigation is made into the potential use-cases of the approach, to highlight the use of the new criteria on several different systems and reliability management contexts.

The pilot tests cover real-time operation on the Icelandic system and system development on the Belgian system. Additional case studies have been provided for the Norwegian system, also covering the context of long-term system development.

Together, the pilot tests have shown that the methods developed in GARPUR are possible to implement in practice, and that they provide useful insights into power system reliability, beyond what the N-1 criterion can provide. Before such methods can be used in practice, a few main challenges were identified. These include the need for expanded data collection and sharing, and further improvements in method speed and scalability. Additional recommendations are made for improved communication and coordination of risk between adjacent TSOs during system development studies.

This short public summary provides single page summaries of the key results from each of the pilot tests and case studies. Extended results are presently kept under restricted access due to the sensitive nature of their content. Some pilot test results will be made available as scientific publications.

The pilot tests showed that there exists enough data in practice to begin building prototype implementations of the GARPUR approach in practice, that it is presently tractable in specific contexts, and that it can provide meaningful insights for decision-making. All approaches are applied to small systems or small segments of larger systems. Further development would be required to scale such approaches up to a pan-European scale. All pilot tests and case studies also highlighted the importance of systematic data collection and the need to ensure that initial data is consistent and of sufficient quality, as well as the importance of tractable and accurate enough system response modelling.

The research leading to these results has received funding from the European Union
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Landsnet pilot test

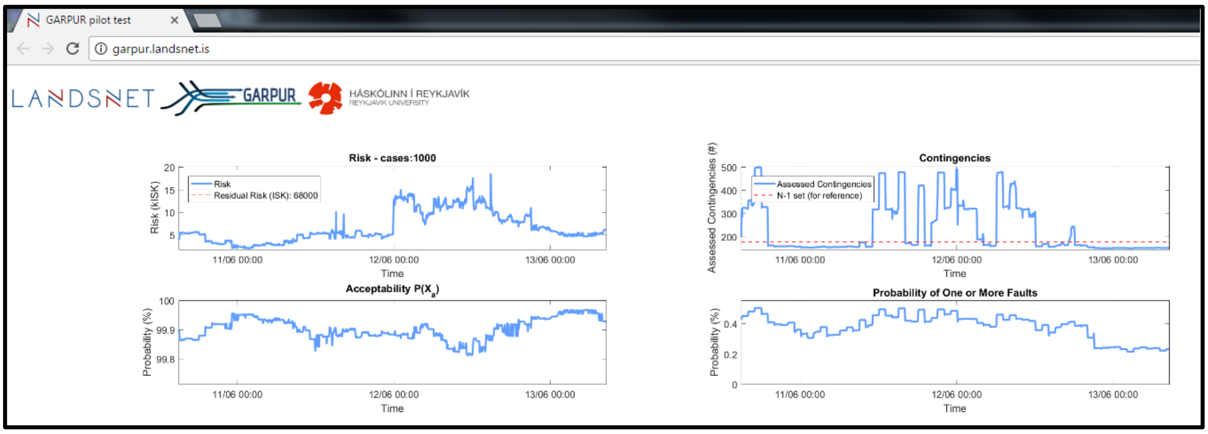
Samuel Perkin (Landsnet) and Guðjón Hugberg Björnsson (Landsnet)

Time frame: Real-time.
Period of Assessment: Operational periods (8 hours to 1 year), with a resolution of up to 1 minute.
Assessment type: Reliability assessment, followed by a study of specific "what if?" control scenarios.

This pilot test assessed the GARPUR methodology on the entire Icelandic transmission system using live system state data from the EMS, with live results displayed in the control room. The test used weather-dependent failure rate models built upon real failure statistics and 10 years of high resolution hindcasted weather data provided by DTU. A custom system response model was built in Matlab, modelling system integrity protection schemes, load frequency control, and under frequency load shedding, among other aspects that contribute to the cascading of faults. The test analysed the tractability of the approach, the runtime, and the dependence of the GARPUR method on weather and system state data.

The pilot test assessed 1000 contingencies on 20 virtual cores in approximately 40 seconds, where the average contingency took 0.8 seconds to evaluate. With a variable contingency list size, the pilot test could reliably update its outputs within 2-minute time intervals. The system response model was the main computational bottleneck, followed by data gathering, pre-processing and output visualisation. The pilot test found that live weather data, and use of weather-dependent failure rate models, was critical for providing meaningful risk and reliability estimates. Finally, the pilot test showed that it could provide meaningful information on the impact of control decisions and on the presence of system integrity protection schemes.

This pilot test showed that the fundamental ideas presented in GARPUR are achievable in practice. In order to achieve an industrial scale implementation, R&D should focus on improving the accuracy and speed of system response models, improving system restoration models (converting loss of load to energy not served), and validating socio-economic impact assessment models. Within industry, further data collection is required on corrective control and restoration procedures, and further coordination and data sharing related to component failures and reliability.



Example of the live outputs of the Landsnet pilot test

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Elia pilot test

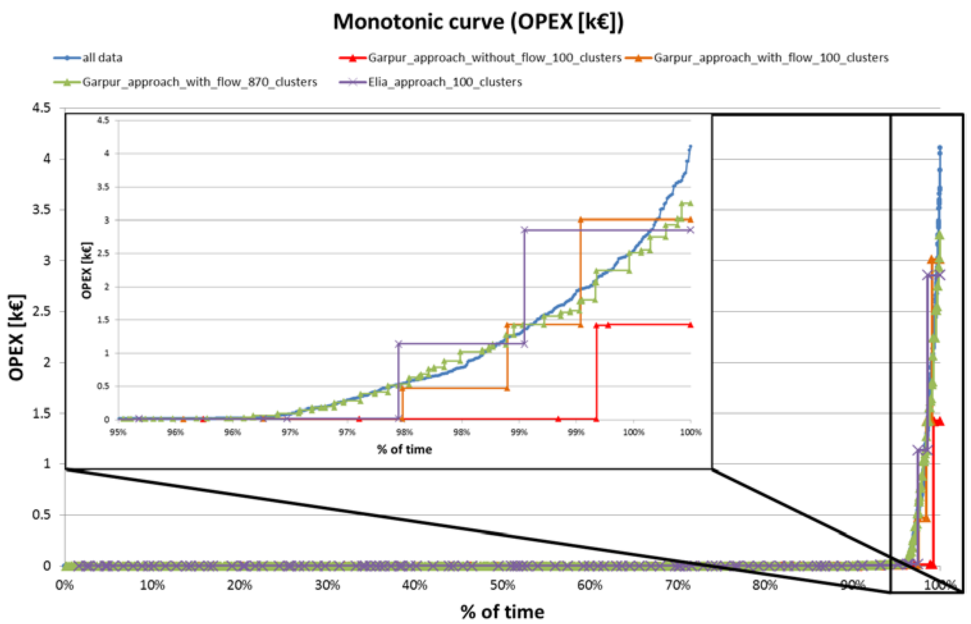
Arnaud Vergnol (ELIA), Weynants Antoine (ELIA) and Waqquas Bukhsh (Strathclyde University)

Time frame: Long term grid development.
Period of Assessment: 1 year.
Assessment type: Comparison between proposed approach and currently used approach in real grid development environment and recommendations for further improvement of the proposed approach.

The system development pilot test of the GARPUR project was conducted by the Belgian transmission system operator ELIA, in collaboration with the University of Strathclyde. It assessed the GARPUR approach for system development, showing how clustering techniques can be applied to system snapshots to create a set of credible future operating states for a future year. These snapshots are then assessed by a DC-OPF algorithm to estimate the operational reliability in terms of operational cost.

The test showed the trade-off between the number of clusters and error in risk estimates, showing that an eight-fold increase in the number of assessed snapshots only decreased error by a factor of two. All assessed clustering methodologies failed to capture the high impact low probability system states, which appear as outliers to the clusters. In addition, the clustering techniques have been used to integrate the maintenance situations, that are common in real-time, in the process of system development. The conditions under which a given asset can be taken out for maintenance are therefore identifiable in advance.

Any new tools should concentrate on minimising the most laborious, repetitive aspects of studies, whilst ensuring that the planner's understanding of the situations they are studying is improved. Operational or development issues that are difficult to model should not be obscured by high levels of analysis process automation within the software. When clustering possible future system states, it is not easy to label the resulting clusters, creating difficulties in drawing clear conclusions on maintainability, therefore further R&D work is required on providing transparency to such methods.



Comparison of clustering technique accuracy

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Statnett case study

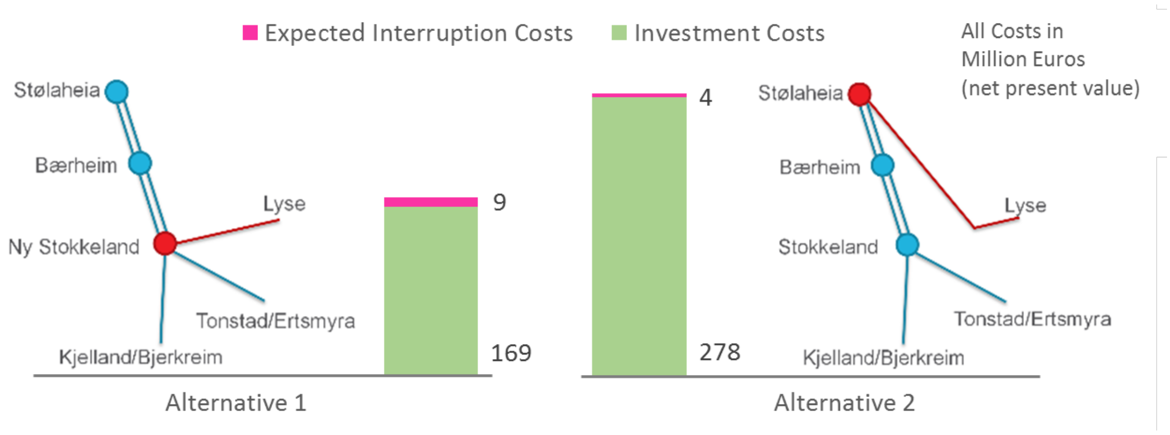
Simon Weizenegger (Statnett) and Matthias Hofmann (Statnett)

Time frame: Long-term grid development.
Period of Assessment: 40 years.
Assessment type: Comparison of different grid expansions by their expected overall costs for society.

Statnett's case study analyses different topological measures in the south-west part of Norway. It is expected that this region needs an increased transmission capacity in near future. This case study compares two expert suggested grid expansions alternatives to ensure a high security of supply. The study applied in-house tools for system response simulation and failure rates adjusted with a Bayesian updating scheme, as well as a ratified framework for calculating the cost of energy not served, to assess the overall costs for society associated with each alternative. Credible long-term load flow scenarios were generated using forecasted load-duration curves, allowing for the estimation of interruption costs over the long-term for the different grid expansions.

The study concluded that the use of probabilistic reliability assessment can result in choosing different investment alternatives in contrast to existing N-1 based approaches and in consequence may results in significant costs savings for society. In this particular study, the value of higher security of supply of Alternative 2 does not defend its much larger investment costs. Instead, the cheaper Alternative 1 can be preferred, which reduces the total costs by 25 % and the investment costs by around 110 million Euros. At the same time the expected interruption costs increase only by about 5 million Euros over the considered assessment period. Further, strict compliance with N-1 would result in system developments occurring sooner than in a GARPUR based approach where each year of delaying the investment results in expected savings to society of 7 million Euros in this case.

In order to perform such studies, significant work is required to develop tools for data collection and handling, as well as in-house tools for assessment. Further efforts were required to develop sufficient graphical user interfaces to visualise results. It is recommended that such tools are developed by experts who both understand the subject whilst having requisite skills to program the presented methods into a tool. Further recommendations are made towards an improved collecting and reporting of component failures, their reasons and their consequences. Main recommendations relate to improve the understanding of component reliability over the long-term, due to weather and ageing, as well as on improving the computational efficiency of Monte Carlo simulation that are used in the tool for system response simulation.



The value of higher security of supply of Alternative 2 does not defend its much larger investment costs. Therefore Alternative 1 is the preferred grid expansion.

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SINTEF case study

Iver Bakken Sperstad (SINTEF) and Ove Wolfgang (SINTEF)

Time frame: Long-term reliability assessment.

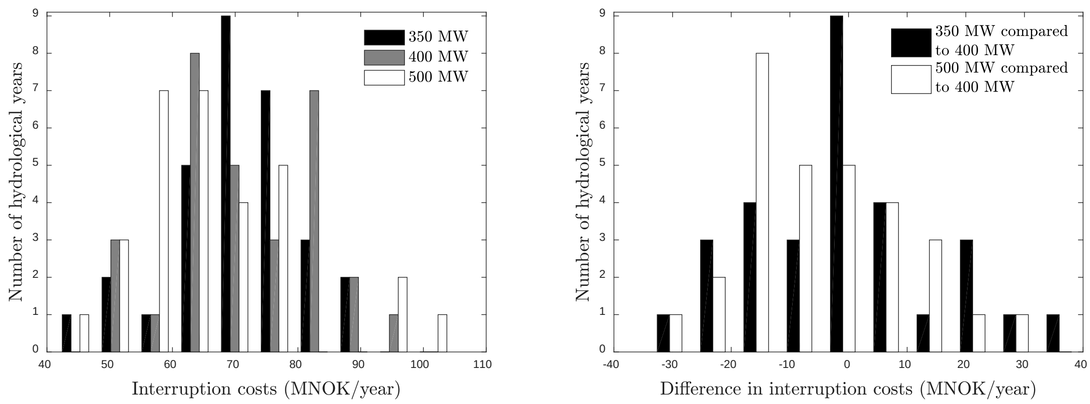
Period of Assessment: 30 years of integrated market and reliability analysis.

Assessment type: Comparison of different transmission limits by their expected socio-economic costs, including interruption costs.

The SINTEF case study illustrates a probabilistic reliability assessment of the Nordic power system in a long-term perspective, focusing on the power system in one particular region of Norway, using an integrated methodology developed by SINTEF for market and reliability analysis (SAMREL). Such a probabilistic assessment of expected interruption costs and other socio-economic costs can allow for a more socio-economically optimal utilization of the grid, supporting the philosophy behind the GARPUR framework. Different values of the amount of transmission capacity given to the market for the interface of a particular region of the Norwegian power system are evaluated based on climatic (hydrological) data for 30 historical years.

A hydro-thermal power market model was used to generate a large number of operating states over the 30-year period which were then reduced to a set of 100 clustered states per year. These states were then assessed using an approach with time-dependent reliability and interruption cost data to calculate the expected interruption costs. The study found that increasing transmission limits for this specific case did not significantly change expected interruption costs, although it would relax constraints placed on the market and hence significantly reduce the power market costs. It was also shown that the impact of climatic variability and uncertainties can be substantial. In general the study illustrates how a probabilistic approach and flexible transmission limits may allow for higher socio-economic surplus.

It is recommended that systematic data management is given priority for real-life data sets, particularly for data that is to be shared among stakeholders. Ensuring data consistency and quality is important for the implementation of such probabilistic methods, which are more data-driven than existing approaches. Accordingly, collection and sharing of reliability data and interruption cost data should be systematically expanded and coordinated. The case study applied a simple representation of short-term system operation within the long-term reliability assessment, and it is therefore recommended that such proxy models are given further R&D attention, in terms of tractability, scalability and accuracy.



Impact of transmission limits on interruption costs (left: absolute, right: relative to base case)

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