The need for a fundamental review of electricity networks reliability standards

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Forward

The EU electricity system faces challenges of unprecedented proportions. Although the electricity transmission and distribution networks have historically delivered secure and reliable supplies to customers, the key issue regarding the future evolution of the network reliability standards is associated with the question of efficiency of the use of existing assets and the role that advanced smart grid technologies could play in facilitating cost effective and secure evolution to lower carbon futures.

The historical network reliability standards and practices require that network security is provided through network asset redundancy, i.e. historical asset based paradigm may contradict the Smart Grid paradigm that focuses on novel, non-network asset solutions to network problems. The historical network reliability standards may impose barriers for innovation in network operation and design and prevent implementation of technically effective and economically efficient solutions that enhance the utilisation of the existing network assets and maximise network users' benefits.

In this context, this paper sets out the case for a fundamental review of the philosophy of transmission and distribution network operation and design may be needed to inform the industry, consumers, regulators, policy makers, in order to facilitate a cost effective delivery of the EU energy policy objectives.

Goran Strbac and Nikos Hatziargyriou
European Technology Platform on Smart Grids

Acknowledgments

This paper presents a summary of the key findings from a very extensive analysis carried out in a number of research projects and particularly from the recent activity undertaken by the UK Energy Networks Association.

1) Context and key problems with the present electricity network reliability standards

1.1. The EU electricity system faces challenges of unprecedented proportions. By 2020, it is expected that 20% of the EU energy demand will be met by renewable generation. In the context of the targets proposed, it is expected that the electricity sector would be largely decarbonised by 2050, with potentially significantly increased levels of electricity production and demand driven by the integration of segments of heat and transport sectors into the electricity system.

1.2. This development, following the established historical design and operation concept would require significant investment in reinforcement of electricity system infrastructure given that (a) variable renewable generation will displace energy produced by fossil fuel plant, but the ability of renewables to displace capacity of fossil fuel generation will be very limited and (b) electrification of segments of the heat and transport sectors might lead to increases in peaks that are disproportionately higher than the corresponding increases in annual energy consumed.

1.3. Although the electricity transmission and distribution networks, designed in accordance with the historic deterministic standards, have broadly delivered secure and reliable supplies to customers, the key issue regarding the future evolution of operation and design practices and standards is associated with the question of efficiency of the use of existing assets and the role that advanced, smart grid technologies could play in the future development and delivery of security of supply to consumers.

1.4. Delivering the decarbonisation targets cost effectively, will require fundamental changes in the historical philosophy of network operation and potentially considerable investment in network infrastructure. However, before the need for additional investment in traditional network capacity can be established, it is critical to ensure that efficient rules that are used to determine the volume of network redundancy that should be provided.

1.5. In this context, a fundamental review of the philosophy of electricity network operation and design is needed to inform the industry, consumers, regulators and governments, in order to facilitate a cost effective delivery of the EU energy policy objectives.

1.6. Establishing the optimal level of network redundancy that should be made available by network operators in real time should balance (i) the value that users attribute to the level of network capacity released, against (ii) cost of reserves, losses, mitigation measures and costs of interruptions caused by outages of traditional network facilities (that will be directly linked with the volume of network capacity released to users).

1.7. An example of different levels of redundancy and network capacity resealed to network users is illustrated in Figure 1, showing a case of a substation with two transformers of 5MW capacity each, supplying different level of peak demand, from 5MW (case on the left-hand side) to 10MW (case on the right-hand side). The first case on the left presents the design that is compatible with historical network reliability standard, providing N-1 redundancy level, requiring that outage of one of the transformers would not lead to demand interruption.

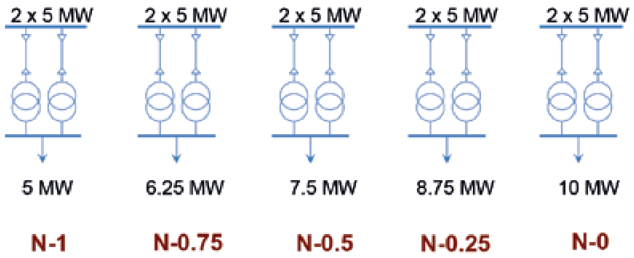

Figure1: Different degrees of network redundancy, reflecting the amount of network capacity released to network users

In case that demand doubles and reaches 10 MW (case on the right-hand side), there would be no more network redundancy left (N-0 redundancy), given that the substation capacity would be fully used under normal operating conditions and outage of a transformer would lead to interruptions of supply under peak conditions (50% of peak demand would not be supplied). The optimal level of network redundancy and hence the capacity that should be released to users, will correspond to the equilibrium when the marginal value to users of the network access equals the marginal costs associated with its provision. This equilibrium position will be different across different system boundaries, will depend on the actual network characteristics, supply restoration, asset repair and replacement processes, ability to control load and may change with weather and other system condition.

1.8. The historical network reliability standards, with the "N-2 / N-1" type criteria and philosophy developed in 1950s and not fundamentally reviewed since, may not accurately reflect the levels of operational risk that the network users actually face, particularly in the context of development of smartgrid paradigm. Overall, there are two key concerns:

- The present electricity network reliability standards may be inefficient and may prevent higher utilisation of the existing network infrastructure and hence may not deliver value for money to network users; In other words, the concern is that the historic network reliability standards may not be economically efficient, as these do not explicitly balance the cost of network infrastructure with the security benefits delivered to electricity network customers.
- The historic network reliability standards require that network security is provided through network asset redundancy (historical network asset heavy paradigm) may fundamentally contradict` the concepts of Smart Grids that focuses on non-traditional solutions to network problems (e.g. demand side, energy storage, real time network control). In other words, the network reliability standards may impose a barrier for innovation in network operation and design and prevent implementation of technically effective and economically efficient solutions that enhance the utilisation of the existing network assets and maximise network users' benefits.

1.9. There is a number of specific concerns associated with the present network reliability standards:

1.9.1. Binary approach to risk:

The binary approach to risk as in the present deterministic network reliability standard is fundamentally problematic: system operation in a particular condition is considered to be exposed to no risk at all, if the occurrence of faults, from a preselected set of contingences, does not violate the network operational limits; while the system is considered to operate at an unacceptable level of risk, if the occurrence of a credible contingency would cause some violations of operating limits. Clearly, neither of these is correct, as the system is indeed exposed to risks of failure and outages even if no single/double circuit outage leads to violations of operating constraints, and the risk of some violations may be acceptable, if these can be eliminated by an appropriate (post fault) corrective action.

1.9.2. Generic reliability rules:

The degree of reliability provided by the deterministic security criteria, using generic rules applied to all situations, will not be optimal in any particular instance as the cost of providing the prescribed level of redundancy is not compared with the reliability profile (cost) delivered. This further highlights the inefficiencies that are inherent in the present network reliability standards. It is important to stress that asset redundancy may not be a very good proxy for security delivered. In this context it is important to recognize that the present deterministic network reliability standards assume that all contingencies are equally likely, which is clearly problematic: for example, faults on a long, exposed overhead line are much more frequent than failures of a closely monitored transformer. Furthermore, probabilities of line outages are usually based on statistics of failure rates accumulate over a long period of time. These probabilities therefore reflect what one might expect if the weather was similar to the average conditions during the data collection period. However, when considering faults on overhead transmission and distribution network lines, only actual rather than average weather condition is relevant. Clearly, during adverse weather condition (during thunderstorms, high winds, ice etc) the probability of failure may be much higher. On the other hand, under fair weather condition, this probability is significantly lower. Hence keeping the same levels of redundancy for all types of circuits under all conditions will be inefficient. In this context recent analysis shows that the present network reliability standards unduly limit the amount of capacity that should be released to network users particularly during fair weather condition.

1.9.3. Impact of construction outages:

The lack of differentiation between construction and maintenance outages in the present electricity network reliability standards may present a significant problem given the expectation of considerable asset replacement.

1.9.4. Impact of Common Mode Failures:

Present reliability standards do not consider common mode failures and do not provide any guidance for dealing with High Impact Low Probability events. Resilience of the network when exposed to common mode failures and high impact events should be explicitly recognised.

1.9.5. System and customer based reliability indices:

Over the past decade, the actual reliability performance of electrical distribution networks in EU has been considered. In other words, regulatory regimes have recently introduced incentives for network operators to minimise the consequences of interruptions, through enhancing supply restoration processes. Although these initiatives represent step in right direction, the focus has been mostly on the system rather than on customer focused indices, which may need to be reviewed, as the security of supply seen by real customers may be radically different from these system level indices used in the current incentive mechanisms.

1.9.6. Non-network solutions:

There is a growing interest in incorporating non-network solutions, such as distributed generation, demand side response, new energy storage technologies, dynamic line rating, automatic network monitoring and control based on new information and communication technology etc., in the operation and design of future transmission and distribution networks. It is not however clear, to what extent the application of such solutions changes the security of supply delivered to the end consumers. This is evidently critical for quantifying the ability of non-network technologies and solutions to substitute conventional network assets. Resilience of future networks involving cyber-physical systems is another area that needs to be addressed in the context of the evolution to smart grid future.

1.9.7. Consumer choice:

At present, choice that network users (both demand and generation) can exercise in relation to their reliability of supply is limited. This may be a barrier for connections, particularly for generation type users. If such choice is to be offered to users, understanding of the network reliability profile will be essential, in addition to the development of reliability differentiating charging / reward mechanisms.

1.9.8. Curtailment of non-essential demand under emergency condition:

Rather than having full interruptions and indiscriminate demand curtailment in case of constraints driven by network outages, it may be possible, with the introduction of smart metering, to reduce non-essential demand, prioritise categories of demand and hence facilitate network management at lower cost to customers, that will lead to increase in service quality delivered to consumers.

1.9.9.Dealing with uncertainty:

Present deterministic network reliability standards specify network redundancy for a given loading condition and there is no explicit recognition of uncertainties. Future electricity system development is characterised by unprecedented level of uncertainties and it may be beneficial to consider this explicitly. Recent research clearly demonstrates that smart grid technologies may provide flexibility to deal with uncertainty, which is not currently included in the network reliability standards.

1.10.A number of specific concerns should be addressed: although some improvements of the existing network reliability standards have been made, this was carried out without reviewing the fundamental principles on which the standard is based. Therefore, service quality profiles delivered to customers by the transmission and distribution networks and cost-benefit performance of the existing standards should be fully understood. This would provide evidence that can then be used to inform debate regarding the strengths and weaknesses of alternative options for future development of network reliability standards including trade-offs between overall efficiency of the standards and simplicity and transparency requirements.

1.11.The need to develop new electricity network planning methodologies has also been recognised in the recent Research and Innovation Roadmap 2013-2022 published by the European Electricity Grid Initiative (EEGI). The Roadmap argues that new planning approaches and techniques are required that can take into account the next generation of electricity networks, potentially characterised by the presence of renewable generation, active demand, storage and advanced network technologies.

2) Smart grid paradigm: development of future network reliability standards

2.1.As discussed, the key issue regarding the future evolution of the electricity network reliability standards is associated with the question of efficiency of the operational strategies used to determine how much network capacity should be released to network users under different conditions and how advanced, non-network assets and technologies could support this capacity release. The cost-efficient transition to a smart grid will require fundamental changes in the historical system operation paradigm in order to ensure cost effective integration of low-carbon generation and demand technologies through the use of new information and communication technology (ICT) and flexible technologies that can significantly enhance utilisation of existing electricity infrastructure. Evolution to smart grid operation paradigm will have major impact on future requirements for network reliability standards, which is discussed below. There is a clear trend in making use of advances in various technologies that can be used to provide the security through a more flexible and sophisticated system operation, rather than through asset redundancy only.

2.2. Smart grid technologies will reduce network redundancy in providing security of supply by enabling the application of a range of advanced, technically effective and economically efficient corrective (or post-fault) actions that can release latent network infrastructure capacity of the existing system. For example, the deployment of advanced communication and information technologies along with recent developments in Special Protection Schemes, Wide-Area Monitoring and Control Systems, Dynamic Line Rating, grid-friendly controllers for Demand Response etc., could substantially increase system robustness to faults while relying less on capital-intensive network infrastructure assets. As discussed, network security against specific disturbances is currently ensured primarily through redundancy in assets and the concept of preventive control. This results in low utilisation of network assets, higher operating cost and potentially increased emissions. Given the recent developments in ICT and control technologies, decision-making will be moved much closer to real-time thus enabling a shift towards a corrective control paradigm.

2.3. Furthermore, the increasing amount of information and data that is starting to become available to system operators along with expanded opportunities to exert system control at various levels and timeframes are rapidly changing the landscape of system operation. Advanced state estimation in combination with increased amounts of real-time measurements obtained via Phasor Measurement Units and smart metering, will increasingly be used to enhance visibility and improve real-time situational awareness. The current challenge pertains how the trend of increasing instrumentation and resulting abundance of different data feeds can be leveraged to improve system security and carbon performance and increase robustness at reduced cost to consumers.

2.4. As the EU system evolves to a low carbon energy system, there will be very significant opportunities for distributed resources such as demand- and generation- led DSR (demand side response) and distributed energy storage to provide multiple services to different sectors of the electricity system. Beyond the provision of voltage support, congestion management, and security services to the local distribution network, embedded resources could also be bundled in intelligent ways, so as to provide various forms of ancillary and balancing services at the national level. Hence, there will be growing need for co-ordinated operation across transmission and distribution networks, which will impact reliability standards of these networks.

2.5. Smart technologies will enable higher utilisation of existing network assets without compromising reliability of supply. A probabilistic Cost-Benefit Analysis (CBA) framework will be a benchmark for assessing different options for the development of network design and operation standards. As indicated in Figure 2, a probabilistic approach can provide the basis for risks of supply interruptions to be understood, quantified and managed through optimising network design (capacity, configuration, degree of redundancy) and emergency operation strategies that should be made available to network users in both operational and investment time horizons. Essentially, this approach will enable the costs of investment (both for network assets and non-network technologies) and maintenance to be balanced against the reduction in operation costs which include the cost of interruptions (loss of supply), cost of constraints (e.g. DG curtailment), cost of operational measures such as the cost of providing emergency generators and demand management, and the cost of losses. The cost effectiveness of preventive and corrective measures in managing the risk should also be assessed using this framework.

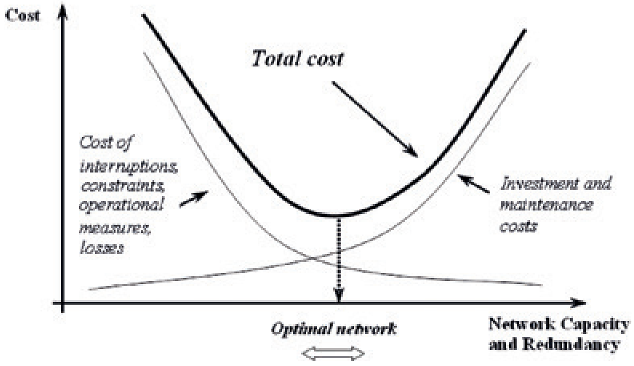

Figure 2: Probabilistic cost-benefit analysis framework for electricity network operation and planning

2.6. Application of the cost-benefit approach would demonstrate that the network capacity that should be optimally released to users, would change significantly with the value that users attribute to network access (i.e. level of cost of interruptions and constraints associated with the particular operating condition), circuit reliability performance, weather conditions, cost of various fault restoration strategies and costs of various corrective actions. Furthermore, initial analysis shows that attempts to fix a single generic value for network redundancy (network utilisation), as in the present reliability standards, may lead to very significant inefficiencies.

2.7. Probabilistic cost-benefit based framework includes all key ingredients required for the development of future network reliability standards to support efficient delivery of a low carbon electricity system. Only probabilistic methodology can provide the basis for risks of supply interruptions to be understood, quantified and managed through optimising the amount the network capacity that is released to network users. The optimal level of redundancy would be determined by carrying out cost benefit analysis illustrated in Figure 2. This framework will hence provide reassurances to all parties, the system operator, the network users, regulators and policy makers that appropriate balance is being struck between costs and benefits in decision making process associated with the release of network capacity in the short and long term. This is important for demonstrating that the network delivers maximum benefits to its users.

2.8. In this context, there may be evolution to probabilistic reliability standards that would enable reliability to be graded below and above the level provided by the conventional deterministic N-1/N-2 criteria, depending on cost and benefits involved. This would provide a framework within which both network and non-network solutions for solving network problems can be objectively compared. This is in line with recent developments (VENCorp, Chile, New Zealand), which is also consistent with the initiatives driven by the development of Smart Grid concepts. UK is currently in the process of fundamentally reviewing the historical network reliability standards, which may provide useful input for wider EU developments.

2.9. In summary, it is clear that a complementary approach that involves a radical departure from the current network design practice may provide the basis for future network reliability standards, as it could deliver significant increases in network assets utilisations with improved reliability performance and hence a significant reduction in cost relative to the present approach. Such an approach would require:

(i) A gradual shift in the source of the system control and flexibility from redundancy in physical network assets to more sophisticated system management, through wider deployment and application of appropriate smart grid control, information and communication technologies, and

(ii) Re-allocation of the duties and opportunities for the provision of system control services to include demand side, distributed generation technologies, energy storage and other modern network technologies, in addition to network primary assets.

2.10. There is clearly a very significant opportunity to shift the network operation and design philosophy from being restricted to solutions based on network assets only to become open to all solutions, one which embraces multiple options and hence deliver smarter, more secure and more cost effective electricity network for all network users and support cost effective transition to a low carbon future. Probabilistic network operation (and design) reliability standards will provide the basis for the development of a 21st century EU transmission and distribution networks.

2.11. Based on the range of evidence provided in recent analysis carried out, including relevant literature surveys, a direction of set of key topics to considered can be listed as follows:

2.12. Cost effectiveness of the present network security standard:

- The optimal level of network redundancy will be case specific, depending on many parameters (reliability characteristics, investment cost, cost of supply interruptions, mitigation measures) and therefore, it may be difficult to implement "one size fits all" standard with the expectation to be cost-effective in all cases.
- Overall, present security standards may be very conservative, dealing with worst-case scenarios. This implies that the present network reliability standard would be cost effective only for "extreme" cases with high failure rates, long restore/repair times and low upgrade costs. In most cases however, particularly at the medium voltage level, the existing networks (both feeders and substations) could accommodate demand growth in the short term, relaxing significantly the N-1 requirement. For reliable networks, with low failure rates and low restore/repair times, the peak load could nearly be doubled without the need for network reinforcement (network could be operated with no redundancy, e.g. at N-0 security as relatively modest increase in interruption costs would not justify network reinforcement). On the other hand, networks with low reliability performance (i.e. higher failure rates, longer time to restore supply or repair asset failures), low upgrade cost, and high customer outage costs would tend to require a higher degree of redundancy compared with networks with relatively higher reliability, higher upgrade cost, and lower outage cost.

2.13. Contribution of Distributed Energy Resources to network security:

- Distributed Energy Resources (Demand Side Response, Distributed Generation and Energy Storage) could support network flow and voltage management and hence substitute for network reinforcement (provided that cost is lower than network reinforcement cost). This can be quantified by employing Effective Load Carrying Capability (ELCC) method, which has been widely used in the past for quantifying the security contribution of renewable generation to security of supply. The reliability value of DER source is defined as the amount of additional demand (ΔD) that can be supplied due to the presence of DER while maintaining the original risk associated with supply interruptions (as shown in Figure 3).

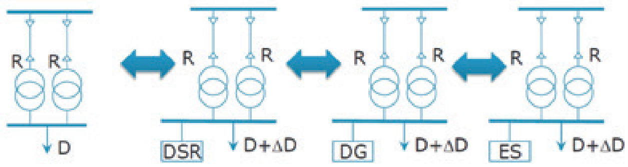

Figure 3: Basic concept for assessing the security contribution of different DER technologies (DSR - demand side response, DG - distributed generation, ES - energy storage)

2.14. Smart management of network overloads through disconnection of non-essential loads:

- At present, network overloads are managed through demand disconnections, with some of consumers being completely disconnected and some consumers fully supplied. The roll-out of smart metering will provide a unique opportunity for smarter management by switching off non-essential loads when network is stressed while keeping supply of essential loads. This would result in a significant enhancement of the reliability of supply delivered by the existing network, as more consumers will have their essential load supplied during network stresses. Furthermore, this will open up the potential for customer choice driven network design. The integration of consumers' preferences in network planning would yield an equitable outcome - consumers with lower flexibility would enjoy higher security of supply at the expense of higher network charges, while consumers with greater flexibility would be rewarded for their flexibility through lower charges. The proposed framework would increase the overall reliability levels without the need for additional network capacity, as it would allow serving of the critical loads during network congestion, in contrast to the traditional practice leading to complete curtailment of some consumers' demand.

2.15. Enhancing network assets utilisation:

- The definition of capacity in the future network reliability standards may allow emergency loading of network assets, given their ability to provide additional capacity in the short-term and hence, reduce the amount of demand to be interrupted. It may be cost effective to increase the life-loss of the assets by overloading these during emergency conditions, as most of the time the assets are operated below the nominal rating. This may require additional sensors to be deployed and further analysis to be carried out to increase assets observability and support real time management of overloads. In addition, the definition of capacity in the standards may also allow and guide the use of dynamic line rating technologies. With the latest technology developments, it is plausible to determine the actual network capability in real time taking into account all important weather conditions that pose cooling/heating effects to bare OH conductors. Important weather parameters would include wind speed and its direction, solar radiation and ambient temperature etc.

2.16. Review of voltage standards:

- Recent analysis demonstrated that voltage management may be important as network capability is frequently constrained by voltage rather than by thermal (current) limits, particularly in rural distribution networks. If the voltage drop beyond current statutory limit of 10% was acceptable during emergency conditions, this could enhance network utilisation. In other words, allowing higher levels of voltage drop would potentially release significant latent capacity which is currently constrained by voltage limits. Therefore it may be efficient to reduce the lower voltage limit as a strategy to accommodate increased demand. In addition to enhancing network utilisation, lowering voltage limit could be used as a strategy to reduce network loading. Recent academic work demonstrated that most of the domestic devices could safely operate at 85% of the nominal voltage at reduced power. On the other hand, increasing the upper limit is not recommended due to security reasons and failure of some devices during the tests.

2.17. Impact of construction outages and asset replacement:

- In the case of longer construction outages it may be economically efficient to provide provisional supply and reduce risks of consumer interruption during asset replacement. These outages may expose the system to greater risks, which in turn, could increase the value of developing provisional load-transfer as a risk mitigation measure. In this context, it may appropriate to consider including guidance for asset replacement in future network reliability standards.

2.18. Resilience of electricity networks:

- Diversity in the portfolio of technologies, network and non-network, will not only reduce the total system costs (cost of investments in network assets, availability and utilisation costs of DER and cost of expected energy not supplied), but could reduce exposure to Common Mode Failures (CMF) and High-Impact Low-Probability (HILP) events, improving the electricity network resilience. The concept of Conditional Value at Risk (CVaR) could be applied to limit the probability of large outages including ICT failures. This may result in marginal increase of network investment and/or costs associated with smart grid technologies and solutions, while reducing the consequences of high impact outages. Furthermore, it may be appropriate to expand the scope of the risk assessment to consider cyber-physical systems, as the failure of ICT infrastructure may cause CMF making network services unavailable.

2.19. Robust distribution network planning under uncertainty:

- Given the uncertainty associated with demand and generation growth, and the significant economies of scale associated with network reinforcement, it will be important to consider benefits of both strategic and incremental approaches to future network development. A number of electricity network planning approaches to address short-term and/or long-term uncertainty could be used to inform the planning strategy taking into account different risk attitudes (e.g. min-max regret approach, CVaR optimisation). Hence, it may be cost effective to consider compliance with the network reliability standard in the context of uncertainties, rather than ensuring compliance against a particular scenario.

- It is imperative to highlight that smart grid technologies could provide highly flexible solutions due to the operator's ability to deploy these faster than major conventional reinforcements. As a result, smart grid solutions may not be the optimal solution in the presence of perfect information, but can be very valuable for managing network constraints in the interim, until some major uncertainty has been resolved. Therefore, a direct consequence of relying on a static valuation framework may not account for the full benefit that smart grid solutions may bring to the network. In other words, future network design standards, supported by appropriate regulatory framework, should recognise the option value of smart grid solutions.

2.20. Long-term optimal design of electricity networks:

- Although in the short term, enhancing network utilisation is a key priority, in the long term, reliability requirements may not be a main driver for future network design. Significant amount of evidence demonstrates that network losses will be a key factor to be considered in planning the capacity and design of future distribution networks. Recent analysis clearly demonstrated that the capacity of distribution networks would need to be oversized significantly above the peak demand requirements, given that the savings in losses exceed the extra cost of oversizing the network. For example the analysis indicates that the rating of an optimally sized low voltage cable would be between 4 and 8 times larger than the peak demand.

- Taking advantage of the large spare capacity, in the long-term it may be cost effective to potentially increase redundancy in distribution networks beyond the level prescribed by the present standard. The optimised capacity and level of network redundancy in the future will provide opportunities for enhancing the coordination of various forms of distributed generation, DSR and energy storage technologies across larger regions, further enhancing the controllability of local distribution networks. These resources could be used to facilitate more secure and cost-effective real-time demand-supply balance and control of network flows, hence enhancing the resilience of the local supply. Supported by suitable ICT, these technologies will facilitate a more sophisticated, real-time control of the distribution networks, also increasing the utilisation of the upstream transmission infrastructure assets.
- As a result of the above factors, a paradigm shift in the network design philosophy may be expected, as illustrated in Figure 4. Traditionally, the level of redundancy reduces and the time to restore energy supply increases, as we move to lower voltage levels. However, the long-term loss-inclusive network design is expected to increase the network redundancy at the distribution networks, while the controllability provided by distributed technologies at the distribution networks may reduce the need for redundancy at the transmission network level. It should be pointed out that at the present, distributed generation is not allowed to operate in island mode in the microgrid paradigm (except in off-grid applications or in the case of providing back-up supply in buildings).
- In this context, concepts of smart district electricity networks (e.g. microgrids, web-of-cells) with appropriate enabling technologies may facilitate the paradigm shift in delivering resilience and security of supply from redundancy in network assets and preventive control to more intelligent operation at the distribution level through corrective control actions supported by a range of enabling technologies and ICT. Smart district electricity networks may be able to mitigate grid disturbances, serve as a grid resource for faster system response and recovery, and strengthen the overall supply resilience to end consumers.
- It is important to stress that the development of smart resilient distribution networks is in line with the concepts focused on the planning, construction, operation, and management of smart cities and energy communities. This is driven by multiple challenges posed by the need to enhance the energy supply resilience in response to growing concerns associated with vulnerability to energy supply interruptions. As a result, there is significant interest in making full use of various forms of local generation (e.g. backup generation) in public or private institutions, combined with various forms of demand-side response and energy storage technologies, as integrating these resources within local district electricity networks would significantly enhance the security of supply delivered to local communities.

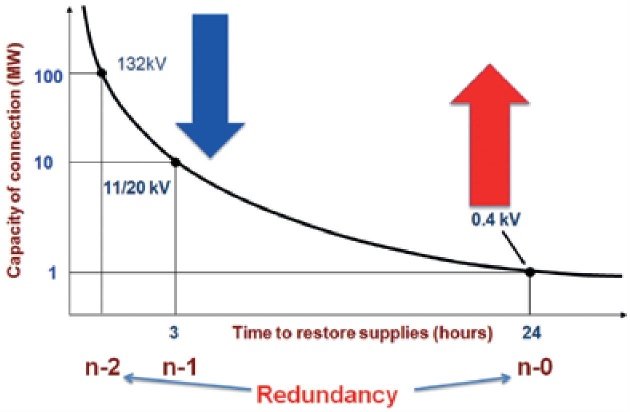

Figure 4: Paradigm shift in network design philosophy enabled by microgrids structures

3) Way forward

3.1. The present network reliability standards compromise the economic efficiency of system operation and may be a barrier for innovation needed to enhance efficiency of network operation and its development. In this context the overarching concern is that the historical approach to network planning and operation is inherently inefficient and will adversely impact the development of the EU low carbon future.

3.2. It is clear that the philosophy of the existing electricity distribution and transmission network reliability standards should be reviewed. Probabilistic framework can support the development of secure and efficient electricity network reliability standard in the context of the delivery of an efficient low carbon electricity system. This would be consistent with the core objectives of Smart Grid concept, i.e. an integrated electricity and information and communication system infrastructure that is intended to enhance the utilisation of existing primary electricity assets.

3.3. Once the vision regarding the fundamental principles of 21st century electricity transmission and distribution network reliability standards is established, the implementation plan for new standards should be developed. This will be a continuous process of gradually transforming the network operation paradigm through adoption of a wide range of non-network solutions to release additional network capacity. There will be instances when it would be relatively straightforward and hence quick to implement new solutions (based on well understood and tested technology), but in a number of other cases, there will be a need for significant developments before a particular set of non-network solutions can be put in practice. In some cases it may be appropriate to set out (small scale) demonstration projects in order to understand and test the performance of the new solutions. Shifting from the current (asset based) preventive to future (intelligent and sophisticated) corrective mode of delivering network security must not adversely affect the risk profile associated with security of supply. Understanding, quantifying and optimising the operational risks will be important and in this respect, our preliminary analysis is encouraging as it shows that the additional network capacity can be released without inefficient increases in risks.

3.4. The fundamental review of the network reliability standards, in setting out the priorities for the implementation, should take into account the immediate need to release additional distribution and transmission network capacity to reduce network constraint costs and to accommodate growing renewable generation through applying available technically effective and economically efficient non-network solutions. In this context, it would be important to set out the programme in the light of new network reliability standards.

3.5. The regulatory framework will need to change to support the migration to the future distribution and transmission network operation paradigm. Clearly, the existing regulation does not incentivise implementation of non-network solutions as an alternative to the conventional network asset based solutions and in this context (together with the network reliability standards) it may not support Smart Grid concepts that involve a shift to more sophisticated system management. Furthermore, network operators should be appropriately rewarded and incentivised to provide additional network capacity through not only asset-based redundancy, but through non-network solutions involving demand and generation and more advanced network management. In order to facilitate this radical transformation in the philosophy of network operation, significant effort, resources and investment will be required, including the need for a number of demonstration projects, and this should be recognised in setting out future regulatory regime.

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