Designing for Renewables

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Energy consumption and climate change are topics that are in the public eye. The Paris Agreement from 2015, dealing with greenhouse gas emission mitigation, sent a strong message and created a climate that is favorable for investment in renewable energy. For many, the transition to a renewable energy future is recognized as central to addressing climate change. Some go as far as stating that we are in the middle of the next energy revolution, with renewable energy being the next logical step after firewood, coal/steam, and, lastly, the "petroleum age" that started in the second half of the 20th century. Distributed energy resources (DER) like wind and solar are destined to play an important role in this energy revolution.

However, there is also a downside: network transmission and distribution operators face the risk of network disruption due to the rapid growth of DER. DER turns the traditional, centralized approach to energy generation and distribution on its head by adding generation capability at the edge of the grid. Network infrastructure that was designed for centralized, one-way generation-to-consumption, needs to accommodate a growing number of prosumers, distributed energy owner-operators at the edge of the grid who both consume and produce energy.

This changes the landscape for distributing energy and makes managing the reliability of the network even more essential, to ensure it can absorb the influx of DER while continuing to operate in a reliable and predictable way. In fact, many aspects of managing electric networks are affected by this, including software for designing network extensions or renewals, which traditionally rely on the use of geographic information systems (GIS) as well power systems analysis. In the era of DER, these traditional ways of working with software applications prove insufficient. This paper discusses what is required to effectively deploy GIS and network analysis capabilities to manage the impact of distributed energy resources on the efficiency, resilience, and sustainability of the electric grid.

The Pros and Cons of Distributed Energy Resources

To get a better understanding of the impact of DER, the chart below illustrates some key characteristics, grouped according to strengths, weaknesses, opportunities, and threats relevant to network transmission and distribution operators:

Strengths

- Business Opportunity
- Diversification

Weaknesses

- Intermittency
- Network Operation Costs

Opportunities

- Climate Change
- Energy Independence

Threats

- Investment Cost
- Local Impact

Figure 1: Pros and Cons of Distributed Energy Resources

Strengths

First and foremost, DER is a business opportunity. It is an opportunity for electric network operators to increase profitability. In the past, projects with renewable energy were heavily reliant on public funding, meaning growth was not necessarily market-driven. However, the costs of installing distributed energy resources have come down over the years. In early 2018, a large-scale wind farm project in the North Sea, without any public funding, was committed to for the first time.[1] Over time, energy operators and prosumers will be able to participate in a dynamic market in which buying and selling energy can become a source of revenue.

Including DER is also an opportunity for diversification, allowing energy companies to spread the risks of generating energy over multiple resources and lessening the dependency on fossil fuels in the process. It helps to balance the books between energy sources that use the already established generation-to-consumption infrastructure with DER that could require new investment in infrastructure, but with the promise of a sustainable long-term source of income.

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Weaknesses

Renewable resources such as wind and solar provide energy at variable intervals and quantities due to their intermittent nature. The intensity with which the wind blows or the sun shines has a direct impact on the amount of electric energy a wind farm or a Solar PV installation generates. Generation peaks and dips create new challenges for planning and operating electricity grids. This potentially affects network resilience, the ability of the network to cope with unexpected changes. Given that the proportion of DER on the grid is growing, the outlook is that the issue of variable generation – and how to mitigate its risks – will become increasingly important, now and in the future.

The increase in generation variability also triggers an increase in cost for utilities because it requires fast-reacting backup capacity, such as batteries and mid-merit fossil technologies (ex. gas turbines). Fast-reacting backup capacity ensures reliability of power supplies when generation from renewable resources falls short. The high upfront investment that is often needed to get DER initiatives started is another cost-related challenge. Although the costs of operating renewables are decreasing (particularly in China and India), when compared to fossil fuel-based energy generation, the initial investment of establishing DER – both on single household and a domestic scale – has arguably been holding back its development in many parts of the world.[3]

Opportunities

For many, climate change is at the top of the list of opportunities for distributed energy resources when looking at the world at large. Where traditional sources of energy production have a negative impact on global climate change, renewables are typically based on energy sources that are safe, abundant, and clean to use. In many countries, there is a political momentum to foster distributed energy growth up to the point that it will outgrow traditional, centralized energy generation and distribution.

Another major opportunity for renewables is energy independence, aiming to lessen – or even remove – the dependency on traditional energy resources. A well-known example in Europe is the Danish island of Samsø, which was transformed into a green powerhouse with onshore and offshore wind turbines, biomass boilers, and solar in less than a decade.[2] Another example is the Dutch island of Texel, which is one of the pilot regions in the Netherlands to deploy smart grids and aims to be energy self-sufficient by the year 2020.[4]

In developing countries, where a fully established energy infrastructure does not always exist, renewables are a major opportunity to get adequate levels of energy generation needed for economic development, even without the upfront establishment of a one-way generation-to-consumption network. In 2016, the developing world invested more in renewable energy than wealthier countries for the first time.[5]

Threats

The energy transition is not without its challenges. Cost remains a major threat to renewable growth. Even though the cost of many forms of DER are coming down – a trend that is expected to continue – the real and perceived costs of DER still play a big role in the public eye. Also, renewable energy must compete in the open market. For example, the abundant and relatively low-cost availability of natural gas in the United States in recent years may delay the deployment of renewable energy technologies.[6] On the other hand, the price of solar panels in 2015 was as low as one sixth of the cost as a decade earlier.[7]

Even though many forms of renewables are not based on burning off finite energy resources, or contribute to climate change through carbon dioxide emissions, this does not mean there is no possible negative local impact on the environment.

Even though many forms of renewables are not based on burning off finite energy resources, or contribute to climate change through carbon dioxide emissions, this does not mean there is no possible negative local impact on the environment. Examples of negative impact include the visual effect of wind farms or solar panels, or the overall impact on a river's catchment area by a hydro energy project. Negative local impact of renewables can lead to legal battles that delay DER projects for longer periods of time.

As more renewable projects utilize batteries as part of their reliability strategy, it comes with the challenge of recycling these batteries when they no longer serve their purpose. There are interesting advances in this area, but they still need refinement to scale them to the point of providing a closed loop.

Balancing the pros and the cons of distributed energy resources is important, and it shows how the benefits are driving further growth; the annual installed capacity of distributed energy is expected to grow globally in the coming decades but also acknowledges the risks.[8] The increase in use of distributed energy makes mitigating network resilience a key factor. How the anticipated rapid growth of DER will affect the risk of disruption and how this will impact the process of extending or renewing electric networks are questions that will be answered in time.

Impact on Electric Network Design

The current and anticipated future growth of distributed energy resources strongly suggests it will permanently affect the way electricity transmission and distribution networks operate. This has a profound impact on the lifecycle of assets, as well as their behavior while they are in operation. Focusing on electricity network design – in both greenfield and brownfield scenarios – is important to learn how DER affects the design process and what role electric design software can play in dealing with required changes.

Merging Disciplines

Traditionally, the main goal of GIS-based electric network design is to accurately document an extension or renewal of the network, describing pertinent characteristics of all the assets that make up a new design, including cables, transformers, pipes, valves, hydrants, and manholes. Embedded workflows play a key role in managing the status of any asset, i.e. "proposed", "in construction", "in service", etc. to keep a complete and up-to-date representation of the grid. On the other hand, products for power systems analysis aim to build accurate models that simulate the behavior of the network. Models are created to assess the behavior of network extensions as well as the entire network, and they are used to manage emergencies and maintenance, find faults, plan contingencies, and recommend changes or adjustments.

> Presently, designs will increasingly include renewals like rooftop solar or small wind farms at the edge of the grid. Using a software environment that merges electric design and power systems' modeling capabilities could help to proactively adopt and embrace the impact of adding renewable energy sources.

Electric network design versus power systems analysis is about network representation versus network behavior considerations. The synergy between these two worlds lies in the fact that network design and power systems analysis share information such as conductors, switches, and transformers, and share properties within those objects that are relevant for both disciplines. Integrating GIS and analysis capabilities has always had the potential of creating a whole that is more than the sum of its parts, but the rise of DER provides additional incentive for merging these disciplines.

Often, designing electric network extensions is done without analyzing impact on network behavior. The impact of a design and the impact to the grid is then only tested after construction, when it is physically connected. Given the strong correlation between distributed energy resources and network reliability, this is a risky strategy. Presently, designs will increasingly include renewals like rooftop solar or small wind farms at the edge of the grid. Using a software environment that merges electric design and power systems modeling capabilities will help to proactively adopt and embrace the impact of adding renewable energy sources.

Integration Types

As a first step towards a more proactive approach, organizations could benefit from establishing integration between electric design – and the GIS-related capabilities it brings – and power systems modeling. The resulting integration establishes a connected data environment that provides a common view of data from multiple sources. Three levels of integration can be identified:

1. Unidirectional data interoperability
2. Bidirectional data interoperability
3. Full workflow integration

Unidirectional data interoperability is useful when building large, complex network analysis models. Building these from scratch can take a lot of time, but taking data from a geospatial data source – often populated and updated by a GIS-based electric design system – and combining it with data from other systems like SCADA, ERP, asset management, and billing systems will more quickly and accurately build models for power systems analysis. Once a network analysis model is in place, an effective incremental update strategy can ensure the geospatial and other asset data sources keep it current, one change at the time, without the need to rebuild the entire model from scratch every time.

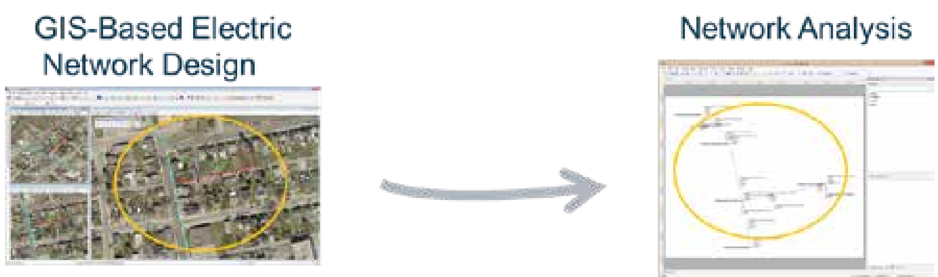

Figure 2: Unidirectional data interoperability

In the case of bidirectional data interoperability, not only is geospatial and other asset data used to create a network analysis model, but a reversed data flow is also established, feeding network analysis outcomes back to the geospatial environment. These outcomes can be extremely beneficial. For example, it is possible to update the values of certain shared properties at the geospatial side with the accurate, calculated values from the network model. Also, network analysis results can be used in a GIS to review distributed energy network changes from a technical, economical, or regulatory angle. Analysis results can further be used to provide decision support, leading to optimized designs of network extensions or renewals.

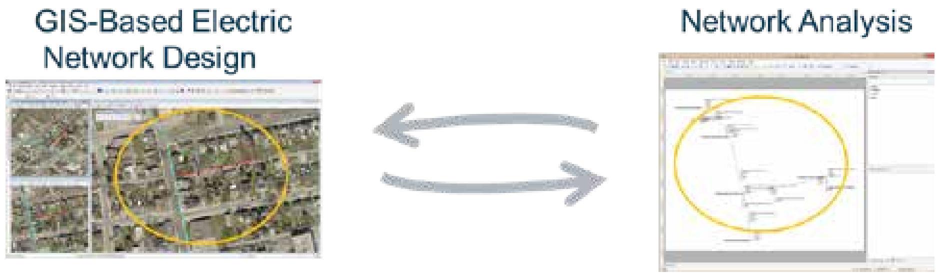

Figure 3: Bidirectional data interoperability

Establishing interoperability is an important step towards integrating the worlds of electric network design and power systems modeling. As the main benefit, it can dramatically improve data quality and accuracy. However, in the case of integrating DER into the grid, even tighter integration might be advisable, going beyond unidirectional or bidirectional data sharing between both worlds. Where electric design traditionally aims at documenting how an electric network will be extended or renewed, what is currently needed is better insight into how an extension or renewal of the network – including DER – will behave. This calls for full workflow integration, including the embedding or cross-pollination of capabilities between systems to pass from one workflow phase to the next without the need to switch.

Enabling Proactive Workflows

To better understand why DER requires full workflow integration in electric network design, a comparison to a commonly found, more traditional reactive design practice is needed. This diagram illustrates this siloed, reactive approach to electric network design:

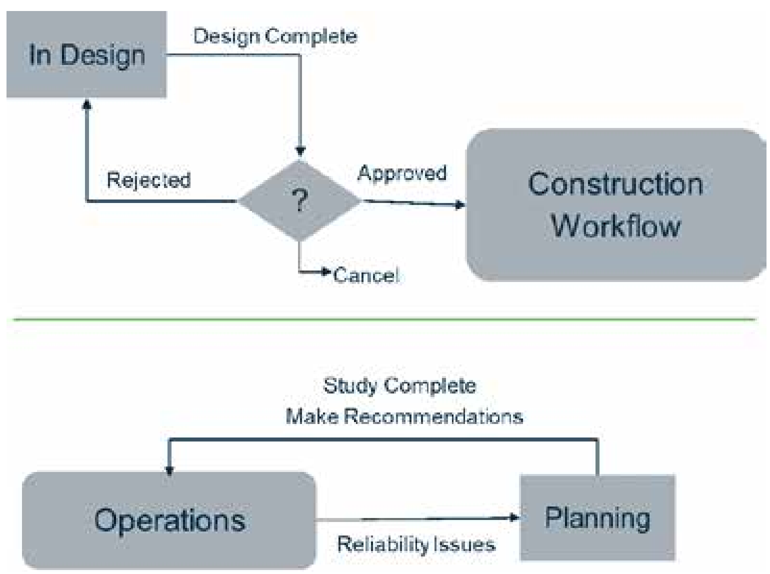

Figure 4: Siloed approach to electric network design.

This diagram shows design activities without considering the potential impact they might have on the network. A design request, which could be as simple as adding a single household to the grid or as complex as adding a series of apartment buildings, is handed to a designer who deals with creating the layout, construction details, and cost estimates and putting the completed design through the approval chain and onto construction.

In this approach, unforeseen patterns that cause reliability issues only surface after construction, often months or years after a network extension came into operation. Once found, these patterns are analyzed by engineers in a separate workflow, leading to recommendations on how the network condition can be improved but without feedback to the original design.

With the growing importance of DER, it can be expected that the time will go down between a network extension going into operation and unforeseen patterns surfacing, and the number of potential issues will increase. This calls for a more proactive approach:

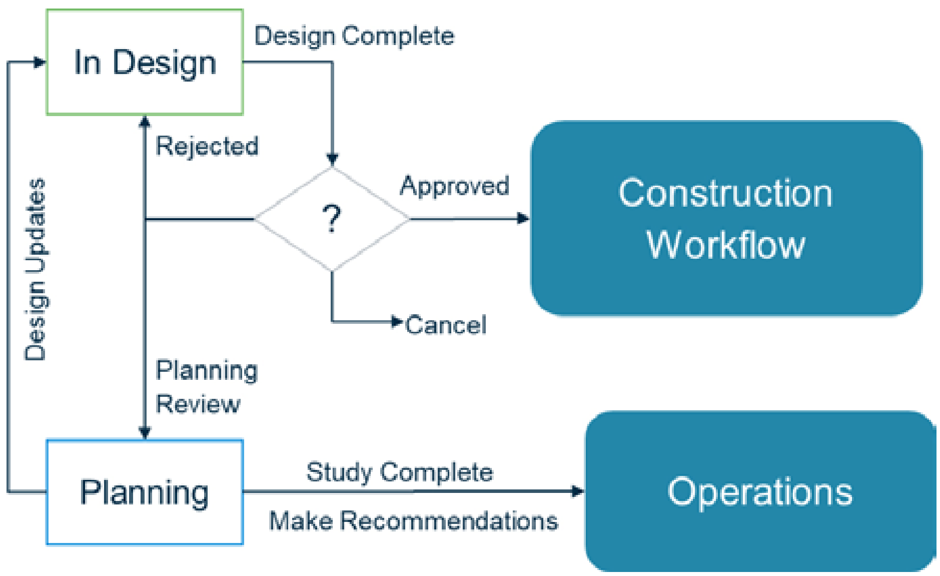

Figure 5: Proactive electric network design.

In this proactive workflow, the designers check if their proposed plans have potential operating issues while they are designing the extension, by checking what they propose against the existing energy infrastructure. They also actively engage with the network engineers, notifying them of potential operating issues in the existing infrastructure, and seeking their advice on changes to the design. If required, engineers can use the input from the designers to make recommendations to operations to prepare for the planned extension of the network ahead of time.

DER-Tailored Design and Engineering

To mitigate risk, extensions or renewals that involve DER require proactive workflows that allow network designers and engineers to collaborate. This requires a software configuration that provides access to both GIS-based design and network analysis capabilities. With the right toolset for the designer and the engineer, both can benefit from a solution that integrates multiple disciplines into a single, integrated software environment.

An example of such DER-tailored integration is to offer the designer the ability to run a subset of network analysis capabilities inside the GIS-based design environment, empowering the user to not just do common analysis like checking whether the connectivity of the design is in order – a typical GIS-based task – but also verifying whether the impact of a design stays within the operating parameters of the existing infrastructure, which is an activity commonly seen as a typical network analysis task.

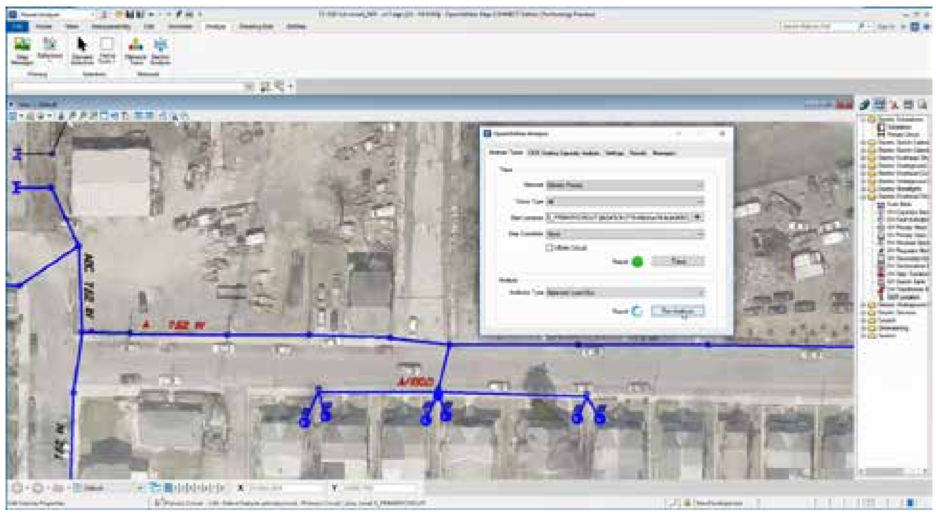

Figure 6: Network load analysis embedded in a GIS-based network design workflow.

In this setup, the risk of adding DER as part of a network expansion or renewal is mitigated first by the designer. If the analytical outcome is positive, there is no immediate need to involve an engineer in the process, although a workflow step could be devised where an engineer gets to approve and review the designer's analytical results. If an overloading issue is found, a next step in the workflow can be initiated that notifies a planning engineer that an in-depth review is necessary. Once the planning engineer verifies the issue, a mitigation plan can be created.

This setup illustrates how an electric design environment combines capabilities found in CAD, GIS, work management, and network analysis to handle the more complex requirements triggered by the growing number of distributed energy resources that are added to the grid. It streamlines the design and engineering process by empowering the designer to execute tasks previously only handled by engineers. It also helps to ensure designs comply with reliability standards to minimize negative impact further down the line.

Summary

Network transmission and distribution operators face the risk of disruption due to the rapid growth of distributed energy resources. The growth of the annual installed capacity of distributed energy is expected to grow significantly in the coming decades on a global scale. In many countries, there is a political momentum to foster distributed energy growth up to the point that it will outgrow traditional, centralized energy generation and distribution.

The increase in use of distributed energy makes network resilience – the capability of the network to cope with unexpected changes – a key factor in energy transmission and distribution. The centralized, one-way generation-to-consumption network infrastructure, needs to accommodate a growing number of prosumers, distributed energy owner-operators at the edge of the grid who both consume and produce energy.

This changes the electrical distribution landscape for good and makes calculating the reliability of the network essential to ensure it can absorb the influx of distributed energy resources. Integration between GIS and the network analysis disciplines can be critical in managing the impact of distributed energy resources on the efficiency, resilience, and sustainability of the electric grid.

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