Are Smart Grids Effective?

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Abstract

Society is in the midst of transitioning from traditional methods of producing energy to methods that are more environmentally friendly and decentralized. This change, coupled with increasing peak energy usage in both the developed and developing world result in energy production and transmission failures. This is where the need for smart grids is highlighted.

Smart Grid systems are reliable due to both the integration of decentralized power production and its response time to an increase in power usage. A major drawback to Smart Grid systems is that they keep track of how and when power is used by the consumer which can be a major privacy and security concern.

To showcase their efficacy, an ecogrid case study with 2000 houses successfully lowered peak power demand by 1.2%. In essence, smart grids are a potential answer to effectively keep up with the changing world by increasing the reliability, makeup and efficiency of energy production and transmission.

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Introduction and Background

Throughout history, humans have moved on from proven energy sources due to a foreseeable consequence from exploiting that particular source. Deforestation and its environmental effects helped us to move away from using wood as usable energy. Following that, humans found a different energy source in coal, with a larger energy density which helped us get to where we are today. Since then, we have found and noted its adverse effects on the environment and have started to move away from this energy dense source.

The goal when improving traditional electricity grids is to avoid blackouts and reduce the stress on the system by using less power when the electricity rates are heightened during peak times. A blackout can be caused by an overburden on the electricity power house based on demands of the customers, or damage caused to power lines due to bad weather, falling trees and other environmental factors. Smart grids provide a two-way communication technology with computational processing aided by sensors, digital meters, automated relays, automated feeder switches and batteries. All the components provide reliable and efficient way of transmitting electricity [1].

Smart grids are an automated way of power transmission and distribution. With renewable technology improvements they essentially become a necessity to properly integrate these technologies. Smart grids allow for more efficient energy consumption as well as greater implementation of renewable sources as energy storage will allow intermittences. These changes to the current grid system would significantly lower greenhouse gas emissions and ensure conscious usage of resources.

Analysis

What results do some of the pilot smart grids show?

EcoGrid EU's smart grid project is used as a case study to demonstrate the efficacy and efficiency of the smart grid. Almost a quarter of all demonstration and development projects take place in Denmark. Denmark's energy portfolio is mostly represented by wind power and industry cogeneration. EcoGrid EU developed the most ambitious smart grid demonstration[1] project in the world and won the *EU Sustainable Energy Award* in 2016 for their efforts [8]. A Danish island named Bornholm in the Baltic sea, served as a laboratory for proving how it is possible to operate a distributing power system with more than 50% of renewable energy sources (RES).[2] EcoGrid was able to attract 2000 of the 28,000 households and 18 industrial customers. The electricity consumption of the island is 268 GWh, heat demand of 500GWh and a peak load of 55MW as summarized in [Table 2].

This location was ideal for a full-scale demonstration as it able to act as an isolated energy system when electrical transmission is interrupted and has a 50% renewable energy recourse penetration. With such a high variable (due to the intermittent nature of wind) distributed energy penetration comes challenges of balancing of demand and supply. A real-time market concept for the distribution network can be used as load balancing. This would essentially balance the power system using prices as a control signals reducing the peak demand and reducing emissions while driving down the cost of electricity.

Overall the project was successful and EcoGrid EU achieved most of their Key Performance Indicators[Table 1]. The system showed excellent demand response to price signals as illustrated in [Figure 1]. The plot is a time-series demand response for the participating groups

[1] The demonstration period was from 2012 to 2015.
[2] Bornholm RES included wind power (30MW), CHP (16MW), PV (2MW) and biogas (2MW).

(except manual and control.) Peak load was reduced by 667 kW (a reduction of 1.2%). Renewable energy share increased by 8.6% when compared to the baseline market utilization; indicating that the smart grid was more effective at using wind power. Cumulative social cost of electricity was reduced by 5.4% resulting in a savings of 38.4DDK/year/house ($5.66USD). These are not individual savings in electricity but are spread out across the entire market (participants and non participants). It should be stressed that these results are produced by 10% population participation; if the entire population were to participate, results would be significantly magnified. Unfortunately, there was no success in resolving distribution feeder congestion, demand response for participants with manual equipment, and meeting electricity reduction targets. It was expected that increased energy awareness would decrease their consumption of energy but that did not turn out to be the case.[3] [9]

Discussion and Conclusions

As society progresses towards more efficient energy, we are challenged to construct and manage infrastructure that is worthy of our demands and easy on the environment. Today, as a society we are in the midst of a transition in energy; transitioning from traditional methods to methods that are more environmentally friendly and decentralized. An upgrade in electrical infrastructure would lead to an array of benefits, with one proven and developed example being the smart grid design. Smart grids can be found in many areas of the world but the most effective one to date is located in Denmark.

While many of the benefits of the smart grid are obvious, there are underlying advantages and disadvantages that hinder the system. One of the major pros would be consumer

[3] This could be due to the fact energy savings had to come with manual adjustments to their systems and participants with automatic heating units had no reason to adjust their units due to their faith in automation.

empowerment, which gives the consumer more energy control and a better understanding of a household's energy usage. In other words, this gives the consumer knowledge on how and when electricity is being consumed. Another major benefit to smart grids is integrated renewable energy, meaning that the system relies on personal consumer renewable energy to balance the grid by investing energy back into the grid. There is still a reliance on fossil fuels during peak hours but with more integration of renewable energy and better technologies, smart grids will become more appealing for cities to convert. Another major benefit to smart grids is stability and safety. These grids are much less prone to blackouts because they rely on integrated power from numerous energy sources. Along with stability, these grids have proven to be safer due to the adaptation of smart appliances that can monitor the system in a real-time view.

With benefits always come disadvantages and there are a few underlying cons that affect the attractiveness of these projects. For one, technology is a major con because as a society we do not have the capability to store energy in vast quantities that would be required to ensure the efficiency of smart grids. The major barrier to why these grids are not incorporated quicker is due to the lack of financial backing provided by the provincial or the federal government. The economics for commercial smart grids needs to drastically improve by reducing the cost of smart grids. There are also employment issues with smart grids requiring a huge technically trained workforce. It has been proven difficult to induce change within an entire society and therefore the transition to smart grids could be a difficult one. However, if the transition is properly introduced there is a large employment opportunity all over the world.

Though there are promising pros and only a few underlying cons, smart grids prove to be the way of the near future. With encouragement from governments and populations across the world, smart grids are the way of the future and will aid in the incorporation of emission-free renewable energy.

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Appendix

Table (1) Relevant KPIs extracted from "EcoGrid EU - A prototype for European Smart Grids" to illustrate the efficacy of smart grids.

KPI #	Description	Result	Fulfilled
6	60 kW total peak load reduction on 500 demand manual houses	29 kW	No
7	175 kW total peak load reduction on 700 semi-automated houses	236 kW	Yes
8	250 kW total peak load reduction on 500 fully automated houses	347 kW	Yes
9	50 kW total peak load reduction on 20 partly automated industries	61 kW	Yes
10	1 % reduction on measured total peak load on Bornholm during the demonstration	1.2%	Yes
16	The RES share should be 5% higher when comparing the metered consumption of the project participants with the calculated baseline	8.6%	Yes
17	The electricity consumption must be reduced by 5% for the participants not in the reference group	3%	No

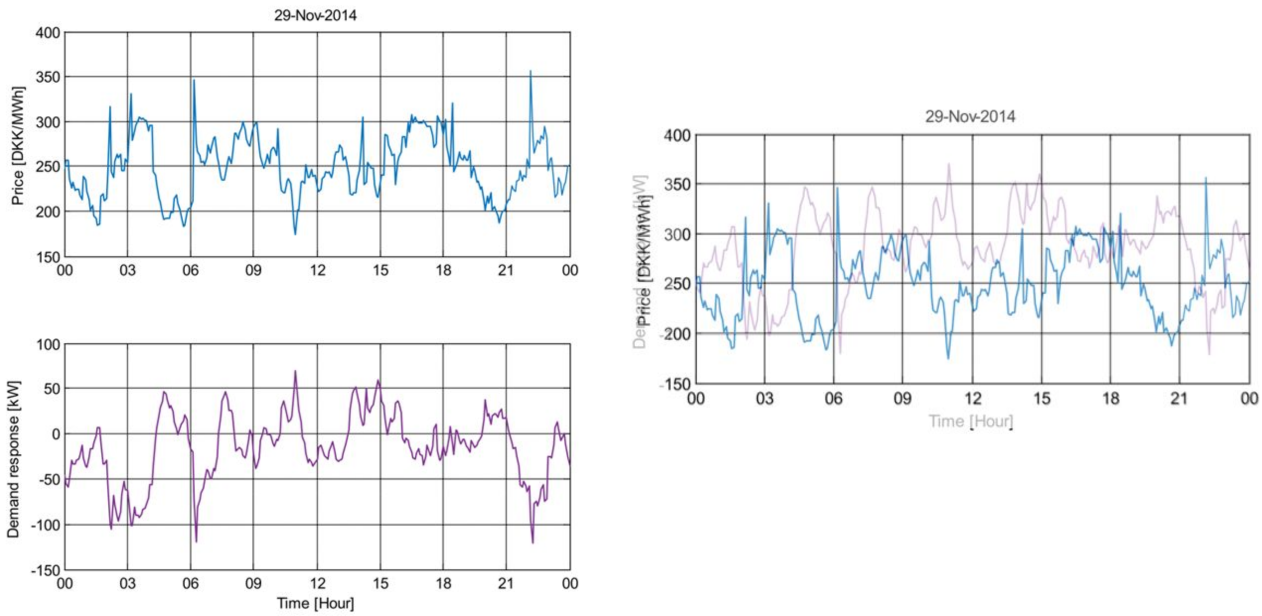

Figure (1) These plots as extracted from "EcoGrid EU - A prototype for European Smart Grids" illustrate the price fluctuations and the activated demand response for that time interval. A make-shift super-imposition of the two plots on the right is created to allow for easier visual inspection.

Table (2) Description of Bornholm energy demand and supply.

Property	Value
Customers	
Number of customers	~28,000
Number of customers (> 100,000 kWh/year)	~300
Total energy consumed	268 GWh
Peak load	55 MW
Low-carbon energy resources	
Wind power plants	36 MW
CHP/biomass	16 MW
PV	2.0 MW
Biogas plant	2.0 MW
Electric vehicles (under roll-out)	
Grid	
60 kV grid	131 km
Number of 60/10 kV substations	15
10 kV grid	914 km
Number of 10/0.4 kV substations	1005
0.4 grid	1,857 km
Communication	
Fiber network between 60/10 kV substations	131 km
District heating	
Number of district heating systems	5
Total heat demand (in 2007)	560 GWh
Operation	
Normal operation mode	Interconnected Nordel
Island operation capability	Continuous

Further investigation on the dimensions of a smart grid?

Smart grids improve efficacy, efficiency and sustainability of electric grids using dimensions such as decarbonization, decentralization, democratization, and digitalization of electrical grid systems.

Currently, when demand outpaces supply, utility providers use 'peaking power plants', which are typically natural gas turbines used only in times of high demand. Due to their infrequent use and traditional design, peaking power plants are expensive, inefficient, and release about 30% more greenhouse gases than their combined cycle counterparts. By using smart grids, the grid can be decarbonized by avoiding the use of peaking power plants while also making renewable energy more accessible. [3] Smart grids also decentralize the electrical grid, allowing communities to gain greater control over the energy they require. This simultaneously increases the consistency of the electrical grid and lowers average costs. The energy sources also become available to diversification as decentralizing the electrical grid allows for distributed generators, or small-scale electricity producers (typically renewable sources), close to the local areas where electricity is required. [4]

Smart grids allow for democratization of the electrical grid, using rule of law to achieve legal equality and homogenize both producers and consumers. This allows for both consumers and suppliers to democratically regulate the grid in a synchronous manner, by requesting or providing energy in a way that suits their needs. [5] Digital devices and IT technologies are required to oversee all capabilities of the power system and maintain stability. By using decentralized energy resources, real-time data and up-to-date information is necessary in regulating the electrical grid. The digitalization of the electrical grid is used not only to inform consumers and suppliers, but also to balance supply and demand and mitigate issues within the system. [6]

Investigation into Smart Grids' ability to streamline renewable energy integration?

Smart grids do a lot to overcome the challenges that renewable electricity sources bring to the grid. Because not all electricity is created equally, smart grids allow variable deliverance to customers that are on an interruptible rate. If there were a lack of wind or a cloudy day, for example, the smart grid would interrupt service to those customers on the cheaper interruptible rate and resume their services when the sun is brighter and the wind picks up. Smart grids also help utility companies integrate and price distributed renewable generation, particularly solar rooftop PV generation. If renewables are to be a thing of the future, solar PV generation will be a large part of it. Furthermore, these PV cells are going to have to be integrated onto rooftops around the world along with sunny remote locations. Smart grids allow utility operators to have full control over these distributed renewable generators and provide them with real-time information on how they are operating. This is of great importance because system operators can then reduce output to load match, and protect workers while providing real-time data on electrical output. Lastly, the huge capital requirement for renewables is a factor that is keeping them from becoming mainstream on the electrical grid. With decentralized, distributed power generation, anyone can become a part of the power generation pie. This takes a lot of pressure of raising capital off of the cash-strapped large renewable project producers while also providing incentive to private investment.

Smart grids allow both supply and demand side options such as distributed generation and demand-side management. Increased storage capacity in batteries and thermal storage also add to the flexibility of smart grids. The increased storage capacity of smart grids makes it much more feasible to incorporate variable renewable resources such as wind and solar into the grid system. The installation of smart grids will help catapult renewable energy sources to make up a larger fraction of the electricity pie. Smart grids are a necessary intermediary stepping stone to making renewable energy more feasible and eventually a reality. [7]