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The Energy Market and Precision Load Shedding

The fight against climate change spans policy, individual action, economic reform, and engineering challenges. At the center of it all, grounding the debates over energy consumption, is the electricity grid. For decades consumer demand has dictated the operation of the electricity grid. Consumers set the amount of electricity needed and grid operators dispatch generators to meet the demand. Dispatchable energy generation enables operators to respond to the peaks in demand. However, it is coal and gas generators that have this essential trait of responsivity. Reducing carbon emissions necessitates finding a solution to deal with peak loads without the use of emission heavy dispatchable generation. The US has made positive strides by building out wind and solar generation. Yet, without the consistency and controllability of coal generated electricity, balancing production with consumption becomes ever more difficult with the rising rates of renewable penetration. In this paper I argue that demand side management and load shedding should play a role in remodeling the consumer energy market to help operators balance the grid and promote social welfare in the electricity market.

Demand Side Management (DSM)

In an electric grid that caters to the consumers, demand side management (DSM) tools flip the script and aim to manage and modulate consumers use of electricity. A paper on demand side management written in the 80s provided the following definition,"planning and implementation of those electric utility activities designed to influence customer uses of electricity in ways that will produce desired changes in the utility's load shape" [2] . The two general goals of DSM programs are peak clipping, "reduction of peak load by using direct load control", and load shifting, or the "shifting load from on-peak to off-peak periods" [2]. The two strategies are subtly different as both look to mitigate the spike in demand that usually occurs in the afternoon. The difference might be summarized as the reduction of peak load vs the redistribution that diminishes the peak load. In the 80s, 'those electric utility activities' that made up DSM programs were "providing information [to consumers], direct technical assistance, financial incentives, special rates, and demonstrations to customers" [2]. All rather indirect ways of incentivizing (basically asking) consumers to avoid using energy during peak hours. While the goals of DSM strategies have remained the same, modern tools have fundamentally changed the nature of demand side management. Smart thermostats and refrigeration, timed water and household heating, and building energy management controls offer direct control over large portions of demand. Interestingly enough, the 1980s paper made note that,"customer purchases of energy-efficient appliances as a reaction to the perceived need for conservation would not be classified as DSM" [2]. However, it is clear now that modern smart tech being purchased by residential and commercial individuals are very much so DSM tools, especially if used in aggregate. This shift in DSM tools with direct control over consumer demand holds a promise that will be examined further in this paper.

Load Shedding

Another tool that grid operators have to deal with peaking energy demand is load shedding. Load shedding is when,"a utility electrical provider lowers or stops electricity distribution across a coverage area for a short period of time" [1]. Whereas DSM activity has historically been a tool to improve grid efficiency, load shedding is a precautionary measure taken to avoid serious problems in the grid or even collapse. A load management tool that acts as a stress relief valve. Load shedding differs slightly from a blackout. Both result in customers losing power, load shedding is executed by the operator while blackouts are uncontrolled disasters. In the US load shedding is seen as a last resort. FERC standards dictate that electrical systems must be designed to a standard of n-1, meaning the grid can withstand the failure of any one main piece of equipment. In NYC we raise the bar by designing the system to be n-2 compliant. However, it is a luxury that our power system is designed to such a high level of compliance.

South Africa case study

In many countries around the world, load shedding is a part of daily life. One notable example is South Africa, who, for the last decade, has been dealing with rolling blackouts[4]. The politics, crime, corruption, and even the assassination attempts that brought the grid to its knees are wildly interesting and worth googling. The simplified engineering analysis is that a decaying fleet of coal plants managed by a public utility cannot keep up with the growing demand for energy. While the country is working towards upgrading the electrical system, in the interim the electric utility has implemented a nationwide load shedding protocol. The load shedding practice in South Africa is very revealing.

Load shedding blocks		
Stage	**Blocks (32-hour cycle)**	**Hours off**
Stage 1	1 x 2-hour blocks	2
Stage 2	2 x 2-hour blocks	4
Stage 3	3 x 2-hour blocks	6
Stage 4	4 x 2-hour blocks	8
Stage 5	1 x 4-hour block, 3 x 2-hour blocks	10
Stage 6	2 x 4-hour blocks, 2 x 2-hour blocks	12
Stage 7	3 x 4-hour blocks, 1 x 2-hour block	14
Stage 8	4 x 4-hour blocks	16
Stage 9	1 x 6-hour block, 3 x 4-hour blocks	18
Stage 10	2 x 6-hour blocks, 2 x 4-hour blocks	20
Stage 11	3 x 6-hour blocks, 1 x 4-hour block	22
Stage 12	4 x 6-hour blocks	24
Stage 13	1 x 14-hour block, 2 x 6-hour block	26
Stage 14	2 x 14-hour blocks	28
Stage 15	1 x 30-hour block	30
Stage 16	Power off	32

Fig. 1 : Load shedding schedule in South Africa [4]

Fig. 1 lists the varying stages of load shedding (stages are 32 hours long). The worst case scenario is stage 16 where there would be no power for 32 hours, but even the best case, stage 1, has a two hour block without any power. Stages are set by grid operators in the days before, and are set based on anticipated supply and demand. While there is almost no chance that stage 16 is reached[4], this planning strategy demonstrates varying expectations for a power grid. Operators and consumers assume that power is not constantly supplied. From the consumer frame of references, the real implications of an unreliable power grid are that the citizens of South Africa lose appliances because of power surges, have to throw out food that passes when the refrigeration fails, consistently lack hot water, and have to plan out there day and work as to have energy when required such as cooking dinner or using a desktop computer[7]. We take for granted the consistency of the power grid in the US. It is upon the assumption of reliable power that industry and engineering are able to flourish.

CSM Vs. Load Shedding

At first glance demand side management and load shedding feel like fairly separate electrical grid operation tools. And as of right now they are. Presently, in the US, CSM encourages users to be more responsible with their energy consumption through pricing schemes and smart energy equipment. On the other hand load shedding is a more aggressive last resort; grid operators cut service to involuntary consumers to prevent grid collapse. However, South Africa’s scheduled load shedding walks a blurred line between both an aggressive CSM tool and load shedding as a consumer side management tool. In South Africa, CSM and load shedding are not so different. This should offer an important lesson to grid operators in the US: instead of passive CSM marketing schemes look to use our modern and active CSM tools to implement smart load shedding programs. To do so, operators must first learn to identify which fraction of the load can be offloaded.

Precision load shedding

In their paper *Load Shedding: A New Proposal*, Roberto Faranda, Antonio Pievatolo, and Enrico Tironi explore how to analyze the total load and partition it to do precision load shedding. Thanks to Smart meters data the nature of the electrical load is able to be partitioned into categories of consumption. Fig. 2 exemplifies the partitioning of a load on the grid in California on a summer day.

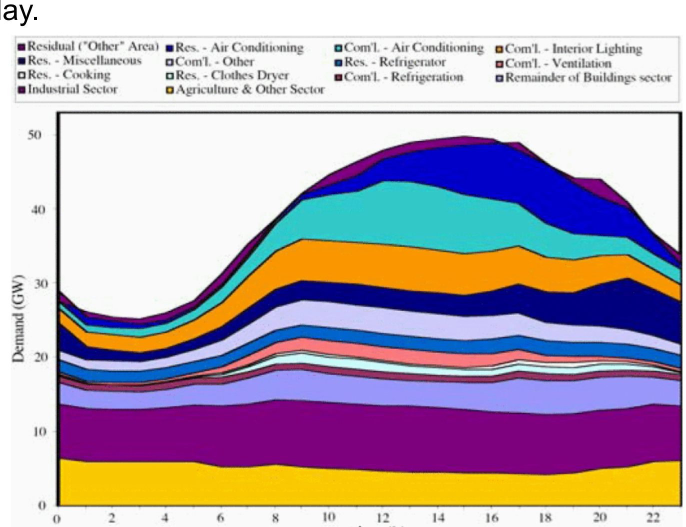

Fig. 2: Partitioned demand, summer day, California[6]

The diagram shows the relative size of each load, and separates the loads with rather high granularity of use cases. Browsing the different load sources, it is clear that the nature of the loads vary widely. Since there is much discrepancy between the nature of each load (size and source), the paper remarks that they can be sorted into two types: interruptible and uninterruptible loads[6]. Interruptible loads included,“air conditioning, lighting, refrigerators” while uninterruptible loads consist of “agriculture and other sectors, industrial [uses]” [6].

The paper sees two paths forward to gaining access to interruptible loads. One is through working with large consumers such as universities, data centers, and commercial buildings. Fig. 3 depicts the electrical load of a university during a winter day and during a

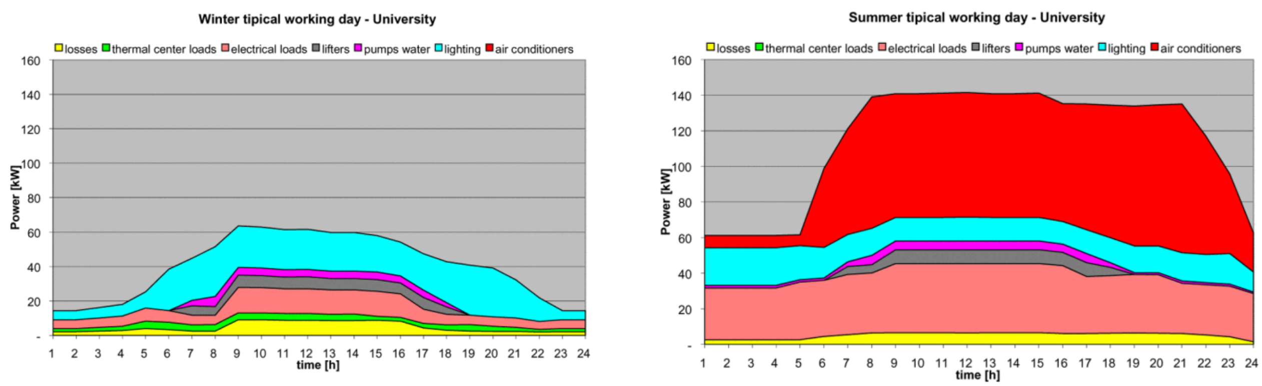

Fig. 3 : University load Winter Vs. Summer

summer day. At its peak in the summer, air conditioning and lighting (both interruptible loads) make up over half of the university's load. Thus, the university has a large amount of load it can shed with relatively low consequences. The other way to gain access to an interruptible load is by aggregating individual loads. The paper models this by indexing from 1 to n customers[6]:

$$S_{I,n}(t) = \sum_{i=1}^{n} Y_{I,i}(t)$$

$Y_i(t) = Y_{I,i}(t) + Y_{U,i}(t)$, where $Y_{I,i}(t)$ and $Y_{U,i}(t)$ are the interruptible and the uninterruptible part of the load.6. Aggregating the interruptible loads provides the utility an interruptible load of meaningful size. Seeing that sizable amounts of interruptible load can be accessed, the paper calls for an update to how we load shed during an emergency. The paper focuses on using the information about interruptible vs. uninterruptible loads to shed load in a more precise manner. If utilities are able to gain control over interruptible loads, instead of indiscriminately shedding whole sections of the grid, operators could cut only interruptible loads. This would mean that not everything loses power,“rendering the effects of lightening to be less traumatic for the end users” [6], as the uninterruptible loads would be saved. While this is a meaningful use case for precision load shedding, it is not the only use case and it doesn’t maximize the usefulness of the interruptible load.

Extending Smart Load shedding

Demand side management tools such as smart thermostats, circuit breakers, meters, fridges, and more are the CSM tools that enable this precision load shedding. These products entered the market on the premise of helping homeowners save money on their electric bill by reducing energy consumption. These tools also offer much more dynamic and controlled use of energy than used to be possible. Previously, the fridge was either on or off, but now smart tech plans out the best path to pull energy from the grid. We should not limit our use of this added control to only during crisis response. Instead, let us leverage the control in the energy markets. As more and more wind and solar energy are brought on to the grid, operators will be desperate for a sense of control over the load in order to keep the grid balanced. Precision load shedding of interruptible loads can be implemented on a daily basis in a way that optimizes the energy market and improves social welfare.

Peak Load pricing

At this point, the reader may be hesitant to start sacrificing the reliability of the grid. One of the core features of the grid is that it is always available. However, the reliability of the US grid was built on the backbone of coal. The nature of the electricity grid is changing, and the markets that represent the grid must change with it. The fixed rate for energy for all consumers under a utility made sense when the cost of energy was the marginal cost of coal. In a grid increasingly influenced by uncontrollable renewable sources, a rigid pricing scheme introduces inefficiencies into the market that produce harm to the consumer.

In fact, for decades, regulators have been working to address the inefficiencies caused by such a pricing model. Regulators have pushed to create a more efficient electricity market by tying the price of electricity more closely to the fluctuating demand. As stated earlier, in the 80s, DSM tools were a variety of marketing tactics and pricing schemes. In NYC economist Fred Kahn served as the chairman of New York Public Service Commission (1974–1977)[3]. While in office, Khan sought to,“adopt regulatory policies that would increase the efficiency with which regulated services were supplied and priced”[3]. Focusing on the electrical grid, Khan advocated the need for peak load pricing. With peak load pricing (also referred to as time of use pricing), the cost of electricity depends on what time it is being used. Higher prices are charged during peak demand, while lower prices are charged on off hours. Kahn noted that with fixed rate pricing, consumers,“will consume too much when marginal costs are higher than retail rates, likely during peak periods, and too little when marginal costs are lower than retail rates” [3]. Highlighting that the fluctuations in production costs for energy are ignored by charging customers one monthly rate. Peak load pricing has been pedaled as a solution to address these inefficiencies for decades. Economist Andres Borenstein showed,“large redistribution from switching from flat-rate to real-time pricing” and emphasizes that,“most customers would benefit from critical peak pricing, and low-income households would not be systematically hurt by it”. His findings emphasize the market desire and consumer benefit of peak load pricing.

Peak load pricing accurately reflects that the price of energy changes over the time of day and year for suppliers, it also reflects that consumers vary in their sensitivity to pricing of electricity for different applications. Elevators, hospitals, and industry production necessitate energy at all times, but I can survive if the lights in my living room are off. Real time / peak load pricing schemes free the market to reflect these consumer side variations in price elasticity.

Right now a kWh of produced and consumed energy is treated as the same for all producers and consumers creating a rigid market full of inefficiencies. Strategies such as peak load pricing that align the true cost of energy with varying levels of demand create a more efficient market.

Failure of Peak Load Pricing

Despite its theoretical benefits, virtually nowhere in the US is peak load pricing implemented. The first reason is a technical one, forever smart metering has been too expensive to implement at scale. The other being that,"retail consumers would not understand or effectively utilize complex rate designs" [3], and peak load pricing would become a way for utilities to charge higher rates for the same product. The technical issue is no longer a problem, "Smart meters send real-time consumption data to the utility and enable various forms of dynamic pricing" [3] and with the maturity of digital data processing, smart meters have radically dropped in price to install and operate. As of 2021 the US has installed over 100 million smart meters [8]. Yet without dynamic pricing, all the meters do is retroactively provide data to utilities for reference when managing the grid. The second issue, consumer hesitation to adopt dynamic pricing, while unjustified, is a powerful and lasting concern. In order to acquire the control over consumer demand that the utility needs to operate successfully, utilities must take the marketing lessons of the 1980s DSM tactics and push the option of precision load shedding rather than peak pricing.

Price Discrimination Using Precision Load Shedding

We have now seen that the modern electrical grid operators need more control over the consumer demand in order to deal with fluctuations in renewable output. With the advent of mass scale smart metering and adoption of smart devices, the technical groundwork has been laid for precision load shedding. Now, precision load shedding should be used to implement price discrimination in energy markets. Instead of charging more for users to use peak load electricity, utilities can create a price discrimination scheme that offers a discounted rate for power to consumers that give operators the ability to curtail their interruptible loads. For example, a smart breaker that controls a home's lighting system and a nest thermostat that controls the AC allows a user to control their lighting and AC loads. The individual can then offer to the utility their lighting and AC loads as interruptible loads in exchange for a reduced electricity rate. The same home does not have to sacrifice uninterrupted power to their refrigerator and desktop computer that they deem uninterruptible. This price discrimination would create the alignment between cost of electricity and the price sensitivity of an individual. The importance of granularity introduced by smart devices and meters cannot be understated. Users can now discriminate between which of their uses of electricity are most important and deem others interruptible. Benchmarks for the amount of electricity that a consumer offers the utility to be subject to precision load shedding, would translate to different rates for electricity. Higher levels of curtailment correspond to lower electricity prices. This gives the user the choice for cheaper but less reliable energy, while maintaining the option of uninterrupted electricity output.

Conclusion

Using precision load shedding to set up price discrimination promises to make the energy market more efficient. Modern smart technology has enabled precision load shedding. Markets are currently inefficient because of rigged fixed rate pricing structures. Introducing higher penetrations of renewables will only make fixed rate pricing a more outdated model with larger inefficiencies. Peak load pricing offers a solution to create a more dynamic model that promotes efficiency by reflecting the varying generation and consumption of modern energy markets. However, peak load pricing has failed to be implemented. Where peak load pricing has failed because of hesitancy towards the pricing structure, the marketing of price discrimination could help with adoption of a new model. Advertising the precision load shedding program as discounted electricity could incentivise consumers to buy into the program. Other means of adoption exist. Companies such as NEST could put in the leg work of aggregating their customers that are willing to be paid to be part of a load shedding scheme. Then NEST or other companies could sell the utilities the interruptible load. The remodeling of the electricity market deserves its own paper. What I aim to have shown is that DSM and load shedding are not being fully utilized in the US. Integrating precision load shedding into the energy grid would help modernize the grid and electricity market.

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