Markets, Stability, and Investment for Resilience, Efficiency, and Affordability

We have an affordability problem and no power to solve it. It seems. PJM's white paper *Powering Reliability Through Market Design* from last month was depressing with only incremental changes to offer. More and more it seems that affordability lies with local DERs, but that is not the full solution especially when most people themselves do not have the financial freedom to invest in DERs.

Affordability in this market is challenging because there are multiple constraints in alleviating scarcity within the system. If we see the power system made up of three phases: generation, consumption, and distribution, there's been a time delay in generation which has thrown the whole system out of balance. Now the system is asking for time back.

Usually the capacity markets are used for planning and transition of generation, so that this delay isn't felt by consumers. But that market is failing to function as both a buffer and an investment signal, further exacerbating the issue.

Variable	Construct	Original System Behavior	Current System Behavior	Failure Mechanism	Takeaway
System volatility	Volatility = deviation from forecast equilibrium	Predictable demand and dispatchable supply	Volatility is correlated across Load and Supply driving extremes and emergency orders	Large Load Growth + Mass Electrification + Weather Extremes (Load), Weather Extremes (Supply)	**Planning cannot assume normal distribution and historical weather patterns, requiring shorter adaptive planning periods**
Capacity Adequacy (RPM)	Capacity = forward commitment to ensure LOLE target	Ensure long-term resource adequacy + investment certainty for new generation entry	Loss of signal: disconnected from real scarcity, unable to drive investment	False Price Ceilings + Regulatory Intervention + Supply Chain Disruption	**Capacity market unable to function as reliable cost recovery signal**
Resource Adequacy Modeling	Framework to translate heterogeneous resources into a reliability contribution metric (ELCC)	Translate diverse generation types into a single comparable measure for LOLE-based planning and capacity accreditation	Annual averaring derates seasonal and temporal performance of diverse generation types	Assumes adequacy is a static energy sufficiency problem: 8760-hour averaging + winter-weighted reliability assumptions distort summer vs winter value	**Adequacy modeling must consider dimensionality of reliability requirements; ELCC should be specific to season or time-segmented depending on different system requirements**
Investment signal (CONE / RPM price)	CONE = cost benchmark for new entry investment recovery	Stable long-run signal for financing new generation	Variable under cost inflation, supply chain disruption, political intervention and forced RMR contracts	Turbine lead times, local interconnection delays and fees reduce certainty of base metric	**Capacity price no longer credible financing anchor**
LSE responsibility model	LSE = load-serving entity responsible for meeting demand	Passive procurement via default service + annual contracting	Unforecasted price volatility across markets, exposing customers to price shocks	Unhedged load + lack of regulatory clarity in enforcing hedging discipline + lack of incentives to actively procure local capacity	**Replace hedge-based logic with enforceable seasonal planning obligations**

Table: Capacity Market Variables - their original function, current failure, and takeaway

Not to mention the clearing price after applying a nice price ceiling no longer communicates the amount of scarcity within the system. Jason Stanek from PJM mentioned that they're not necessarily married to capacity markets, but divorcing the capacity markets still does not solve our affordability and scarcity issue.

The system is asking for time to catch up. The obvious question and my own biased perspective is well, isn't that what batteries and energy management systems are for? But we run into the same issue of investment again. Just on the lending side. Batteries are not traditional power resources. They are valuable because they provide stability through the ability to plan, which does not have the same value as traditional gas power plants. Batteries are valuable because of their operation, not their generation.

One of my developer friends working on battery projects said "every assumption is a discussion". Batteries are financially powerful because of their operation and ability to generate revenue through price arbitrage across various markets. But that is not investor friendly. Investors do not fund projects based on speculating how well a bidding optimizer can game the markets. They require stable long term non-merchant revenue that can build a trustworthy amortization schedule.

If we go back to the three phases of the power system we need to add a time delay to consumption and distribution. Similar to a control system, we need to use time-delayed feedback to stabilize an unstable system. What does that mean? We need to plan and operate around scarcity and financially value stability. The present-day capacity market only tells us that we're short of power and that we don't have enough to meet peak demand. But if we can operate the system to ensure those scarcity events don't occur or occur at a lesser extreme, we can bring stability into the system within its current limitations.

Stability Markets

What if we had a market that rewards stabilizing the system around scarcity events?

When the grid lacks enough generating capacity a scarcity event occurs resulting in shortage pricing, where PJM allows wholesale electricity prices to rise significantly. In the first three months of 2026 alone, there were [86 intervals with five minute shortage pricing](). So scarcity and shortage pricing is quite common.

Imagine it's summer and ahead of the season, PJM has determined that we are expected to have 200 scarcity events. The grid is stressed. We already had a load management event in [mid-May]() and thankfully demand response across the LDAs worked. But that's a bit reactive and we want to be proactive in the way we operate. **We ask our resources, are you willing to optimize your operations to prevent or minimize scarcity events? Can you promise to bring stability during scarcity?**

What is the financial value of having stable operations? The inverse - the cost of unstable operations. Instability and scarcity has resulted in not only shortage pricing in wholesale markets but also [paying extra for Reliability Must Run (RMR) resources](). Both of which are paid for by the end consumer - us ratepayers. We have to be cognisant about the missing money issue in markets and recognize that additional operation agreements are paid by the end customer. A **stability market** should be designed in a way that incentivizes participants enough while ensuring the payment of their services do not exceed avoided shortage pricing and RMR payments.

An effective stability market should result in avoiding scarcity events and therefore avoiding shortage pricing payouts and transmission constraint penalty factors. An effective stability *market should also result in the release of RMRs allowing units wanting to retire, to well retire. It's incredibly expensive to operate and maintain power plants that are well past their prime.*

Affordability Constraints

The affordability constraint should function as a price ceiling of the stability market. **The total payout for the stability market should never exceed the cost savings of avoiding scarcity.** From a planning perspective any entity responsible for serving load whether it be the ISO or the LSE, should have an estimation for the amount of excess energy demanded that causes a scarcity event and how much scarcity costs the system. These two values can be used to determine the average cost of scarcity per unit of energy (MWh). That value of average cost of scarcity per unit of energy could potentially serve as the effective **price median** for the **stability market**.

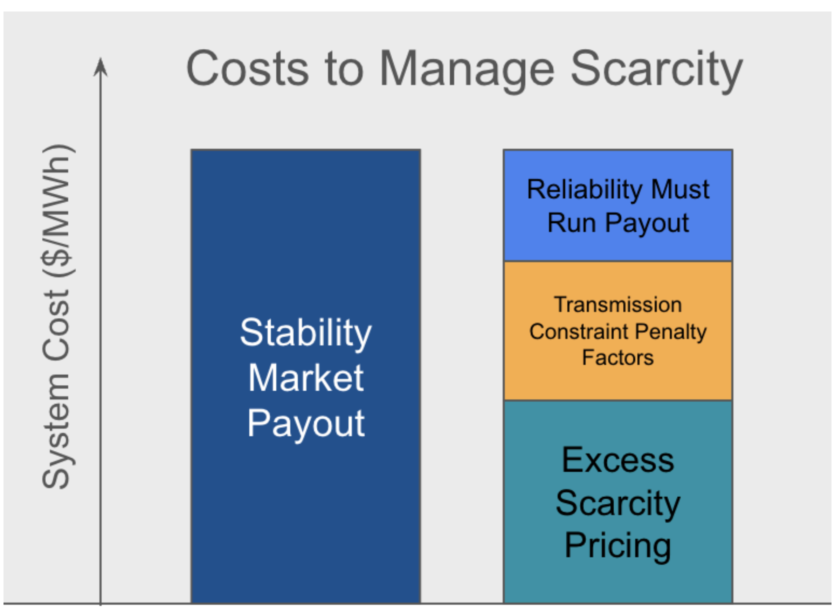

Figure: System Costs to Manage Scarcity Capping Stability Market Payout

I say price median because if this market is meant to manage scarcity and foster stability, a price ceiling will effectively devalue stability and possibly hinder participants from offering stability as a service. I do think if there are more stability resources, the payout should be lower to again ensure the amount of money being spent in the system is conserved. And if there are less stability resources, the payout for those offering stability should be higher.

Participation Rules

So what could be the rules to enter this market? If this market is meant to foster stability, there must be a performance guarantee for participants, a reward for exceeding performance, and a penalty for underperformance. The stability market should be a long-term planning tool but actors should be awarded retroactively in a double-causer pays system based on performance.

For example if I am a 100 MWh 4 hour battery, I can move 25 MWh of energy within an hour. And the period of an hour matters because reliability is measured over the hour. If I participate in the stability market I guarantee to avoid 50% of scarcity events. I bid 25 MWh with a 50% performance guarantee into the stability market. If I am able to prevent or minimize 50% of scarcity events over the whole year I will be paid the 25 MWh x the stability market clearing price x 24 hours of performance (planning and operations period), which should translate to 25 MWh of energy that did not result in scarcity pricing. However if I am unable to perform as expected there are penalties. I should incur the excess scarcity pricing payouts that I guaranteed to help the system avoid over the hour. This will be paid out directly to stability market participants who were able to perform during those events.

I strongly believe that if a resource is operationally meant to stabilize the system, it must be rewarded and penalized accordingly. I also strongly believe in a double-causer pays system as performance becomes self-funded and sets up competition between resources to actively stabilize the grid. Again biased but the [double-causer system was implemented in Australia] after a whole region, Queensland, was islanded after a frequency event. It has resulted in renewable energy resources and batteries continuously optimizing operations to keep the grid stable.

Scarcity events can be unforecasted, but that is also the point of a good optimizer leveraging good forecast models. It helps emerging battery systems and their chosen optimization platforms to perform and build a track record for investor confidence.

Location Granularity

This stability market would have to be location specific. Scarcity pricing is based on locational marginal pricing nodes but could be brought up to the zone or hub level. Transmission constraint penalty factors would be based on which constraint was avoided. And RMRs are at the LDA level. All of these locational resolutions should be applied to the stability market but realistically the planning should be at the LDA or possible LSE level. If applied at the LSE level, the LSE could be responsible for the planning and operation of the market. The rules and constraints of the market would be the same and could serve as a high-level flavor of [dynamic pricing].

Seasonal Planning

Originally this paper started out by questioning why reliability ratings from capacity markets had a winter weight while peak load and allocation of costs was determined through summer peak loads. Any type of stability or [capacity planning should be done at the seasonal level]. This is primarily because the load is so different in the summer vs the winter and generation also performs differently. It does not make sense for all resources to be evaluated homogeneously over a whole year because it devalues when some resources perform the best and even have environmental benefits.

It is obvious why generation is different across seasons, but load is also different. And if meeting the load is the primary driver and responsibility of markets, that should be reflected in planning and development of the system's requirements. During the summer we have AC-driven load which is primarily induction motor driven meaning reactive power heavy. In the winter we have resistive heating which is mainly active power. This matters because a system with higher reactive power requirements has different stability parameters - voltage regulation is more important in the summer. The type of generation that is best suited for the summer is inverter based resources. Inverter based resources are able to dynamically manage the amount of reactive power they output into the system ensuring that the system at least at its point of common coupling remains stable.

Voltage regulation is becoming more important as our system becomes volatile. The lack of voltage regulation and reactive power control resulted in the Iberian Peninsula event last year. Voltage regulation smooths spikes in supply and drops in load. As a system we are relying on demand response for stabilization but sudden load shifts can cause voltage stability issues. That's why those data centers dropping off the grid in May caused NERC to issue a Level 3 alert. If we don't have enough inverter based resources smoothing that drop in load, we are very likely to have major stability issues and have contingency events that affect whole regions.

Wrap Up

A market operator like PJM is meant to be good at planning to keep the system stable. They are responsible for ensuring that markets are set up to reward participants for providing power and frequency response, but since we have a whole new set of resources that improve operations, those resources should be allowed to perform at their best and be rewarded accordingly. And similarly if a system has different load needs, profile characteristics, and stability requirements based on the season, then the system should have specific planning per season to ensure the system stays stable throughout the year.

Finally from an environmental perspective, solar power is not only beneficial as an inverter based resource that provides reactive power support but it also does not produce greenhouse gases. Using fuel-based resources like gas turbines during the summer puts a lot more heat into the system, the greenhouse gas effect is strongest when it's warm and humid. Heat domes, water vapor, and infrared radiation traps more heat and more emissions during the summer. In contrast during the winter, carbon dioxide and methane stay trapped in the ground for long and the surface emits less radiation too. It makes sense - solar power during the summer, and yes fuel-based resources during the winter. It’s possible a seasonal planning cycle can benefit us in more ways than one.

It’s important that we talk about grid stability and ensure that resources are compensated fairly. But we cannot forget about the environmental implications. Our system is more unstable and we keep encountering peak demand because our weather is getting more extreme. We can fix it on one side by ensuring markets are good, and LSEs perform demand response, and batteries are investor friendly. But we need to remember how we produce energy matters and affects each and every one of us. We are in a mass affordability crisis because the earth’s systems are experiencing disruption.

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