Reform of PJM's Resource Adequacy Market Design
Daymark/EKPC Package #1

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EAST KENTUCKY POWER COOPERATIVE
A Touchstone Energy® Cooperative

Overview

THIS PRESENTATION DETAILS EKPC'S PACKAGE #1 PROPOSAL

- EKPC's working definition of capacity is the planned for capability of a resource (physical asset) to deliver energy or provide ancillary services to firm load in each hour
- The purpose of the capacity market is to procure the lowest cost portfolio of capacity that meets the resource adequacy target (i.e., measured using LOLE/EUE)
- A good capacity market design supports efficient allocations of capital and coordinates the timely entry and exit of resources, consistent with maintaining regional reliability
- Cleared capacity must have the opportunity to recover its net going forward costs
- A resource must be able to manage/mitigate the risks it takes on when assuming a capacity commitment; a highly punitive penalty structure is counter-productive
- PJM must respect the operating constraints of the qualified capacity that it accredits and clears in the capacity market and recognizing these constraints schedule capacity resources to meet real-time load to ensure reliable operations
- The market must allow *self-supply* to meet resource adequacy obligations; the capacity market must not impose a preferred portfolio on a load serving entity

Reliability Risks and Drivers

- EKPC adopts PJM's hourly risk modeling, including weather, ambient air reductions, production profiles, and forced outages
- Scheduled outages are accounted for in (hourly) requirements modeling and clearing
- Risks associated with extreme (outlier) weather, outage, and fuel delivery force majeure will be modeled as emergency conditions
- Identified and modeled common mode failures would be reflected in emergency capacity requirement modeling
- Locational deliverability will be represented using a modified transmission system planning model topology enforced in clearing

Procurement Level and Metric

- **Requirements are solved for in the clearing and are a function of the load forecast and the characteristics of the bid resources**
- Reliability targets are Expected Unserved Energy [EUE (magnitude)] and Loss of Load Expectation [LOLE (frequency)]
- We propose two products: **Base Capacity (BC)** and **Emergency Capacity (EC)**
- **BC requirement** is set to meet expected load (the mean of the hourly load distribution from the PJM load forecast) plus base reserve (an amount above the expected load needed to satisfy the LOLE/EUE clearing constraints in all hours given the characteristics of the bid resources)
- **EC requirement** is set to meet extreme load (the mean of all load to the right of the expected load on the hourly load distribution) plus emergency reserve (an amount above the emergency load needed to satisfy the LOLE/EUE clearing constraints in all hours given the characteristics of the bid resources)
- Load forecast distributed to load nodes pro-rata on historical like-hour demand. Injections from capacity resources will be modeled at point of interconnection. Transmission explicitly modeled (perhaps with some simplification). The clearing is transmission constrained; quantities cleared and prices reflect transmission constraints binding each hour
- Procure 100% of the demand in the BRA. PJM buys or sells in Incremental Auctions to true up to revised load forecasts
- FRR entities have BC and EC requirements. An entity may choose FRR for one or both, or only a portion of either. Any requirement not satisfied as FRR would be satisfied in the capacity market

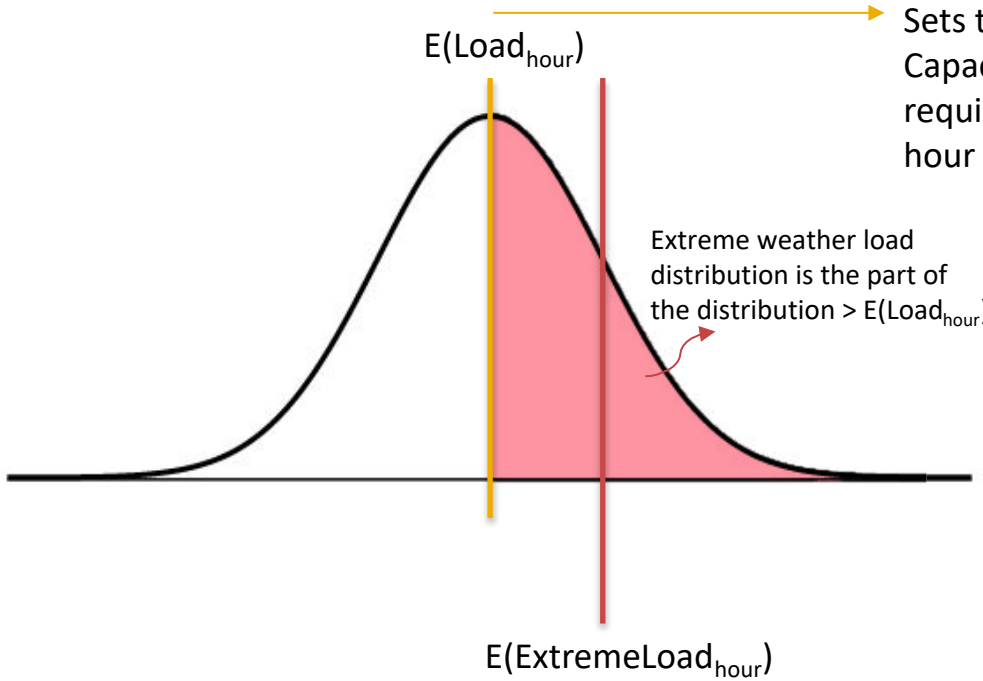
Requirements Setting (structured to illustrate concept)

- BC requirement = hourly expected load + reserve margin_B
- EC requirement = hourly extreme load – hourly expected load + reserve margin_E

Requirement Setting Process: Example (1 of 2)

For hour i,

i^{th} hour load distribution



Optimized Market Clearing subject to LOLE and EUE constraints

INPUTS: Hourly Load distributions, resource characteristics

Market cleared based on BC and EC requirements

LOLE and EUE computed based on cleared resources and load, weather distributions

if $LOLE_{modeled} < LOLE_{target}$ or
if $EUE_{modeled} < EUE_{target}$

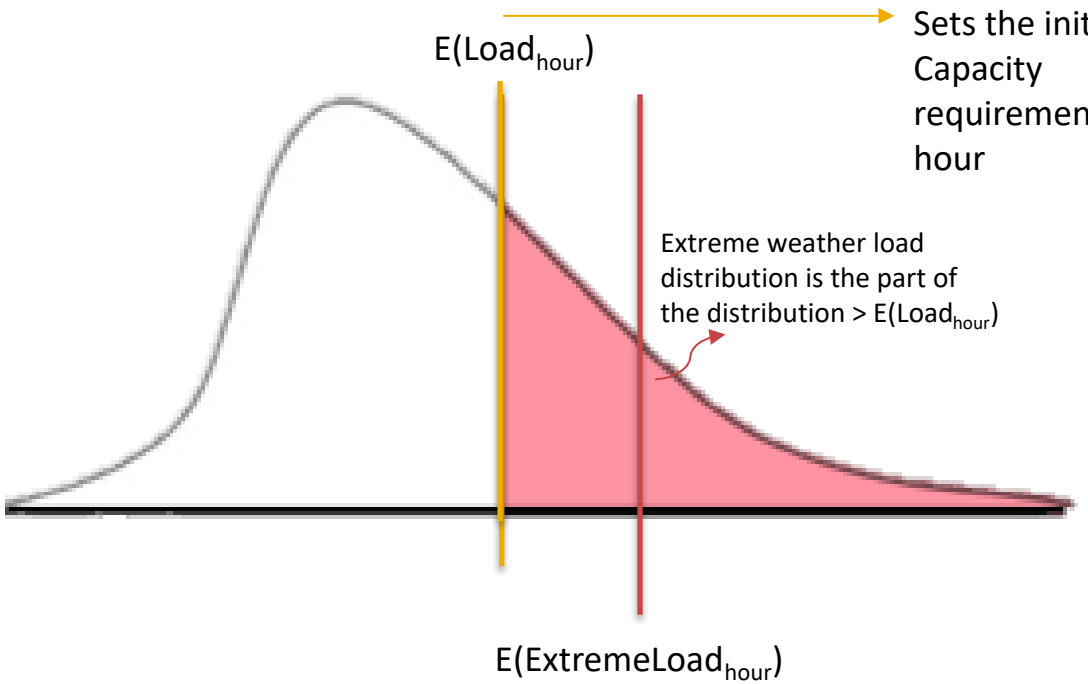
Increment by Reserve Margins on Base and Emergency loads

E(X) = expected value of X

Requirement Setting Process: Example (2 of 2)

For hour j,

j^{th} hour load distribution



E(ExtremeLoad$_{hour}$) - E(Load$_{hour}$) → Sets the initial Emergency Capacity requirement for the hour

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Increment by Reserve Margins on Base and Emergency loads

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Resource Qualification (1 of 2)

- BC is structured to cover expected load, subject to reliability targets
- EC is structured to supplement BC under extraordinary conditions ("black swan" events) and serve extreme loads, subject to reliability targets
- All resources must be fully deliverable to firm load
- All capacity meets NERC minimum requirements (EOP-012-1)
  - BC has no special “winterization” requirements beyond those recommended by NERC (different from PJM)
  - EC must have the ability to operate through extreme temp/humidity conditions (taking into consideration PJM's enhanced winterization concepts)
- BC and EC must demonstrate maximum dependable output (ICAP) via periodic testing
- Qualified ICAP is limited to CIR value

Resource Qualification (2 of 2)

- EC can be provided from the top end of a resource that is in a normally on-line state (e.g., a steam unit) or from a resource that is in a normally off-line state (e.g., a peaker). The inclusion of the ability to supply EC from the top end of a normally-on resource recognizes that under extreme conditions already on-line resources are most likely to continue to perform and are frequently postured in operations to supply reserves for that reason. In the operations time frame, should an EC resource not be picked up in economics, but PJM operations determine additional resources are needed to address a likely reliability condition, posturing EC resources, up to and including committing resources that have sold EC off the top end of their operating range, is an appropriate action
- EC must also satisfy the following:
  - Meet all BC requirements
  - Respond to PJM dispatch instructions under emergency conditions
  - Have a verifiable firm fuel source (e.g., on site fuel or firm fuel supply and delivery contracts) that allows for continuous operation for at least 24 hours
  - Demonstrated financial capacity to absorb non-performance penalties.
  - The EC product is intended to be technology neutral ... at some point technology may allow other resources to meet the performance expectations of firmness. The example of the firmness isn't intended to limit the product to thermal generation

Resource Accreditation

- **Accredited capacity** is the maximum amount of capacity that can be offered into the capacity market auction. The accredited value is an accounting value that simplifies the process of making a capacity offer and performing capacity market settlements
- The accredited MW, called UCAP, is the average of the hourly *Adjusted ICAP* values
- **Adjusted ICAP** is the qualified ICAP modified to reflect weather correlated ambient air reductions and outages in each hour
- For accreditation purposes, Adjusted ICAP can be assessed using the same resource classes suggested by PJM.
- DR and EE availability should be modeled in a way consistent with other resources, see PJM proposal
- Modeled resource mix for accreditation purposes reflects the resource mix used in reliability modeling; appropriate weather data will be used to adjust outage rates, ambient air reductions, and production profiles
- The accredited MW is set to the average of the hourly Adjusted ICAP values for each class times a unit-specific adjustment factor

Resource Accreditation: Example (structured to illustrate concept - no actual data)

Thermal Resource							
ICAP	50.0	MW					
UCAP	40.5	MW					
Sample Days				Sample Days			
183	Adjustments			182	Adjustments		
Hour	Availability	Ambient air	Adj ICAP	Hour	Availability	Ambient air	Adj ICAP
1	0.8	0.98	39.2	1	0.95	0.88	41.8
2	0.8	0.98	39.2	2	0.95	0.88	41.8
3	0.8	0.98	39.2	3	0.95	0.88	41.8
4	0.8	0.98	39.2	4	0.95	0.88	41.8
5	0.8	0.98	39.2	5	0.95	0.88	41.8
6	0.8	0.98	39.2	6	0.95	0.88	41.8
7	0.8	0.98	39.2	7	0.95	0.88	41.8
8	0.8	0.98	39.2	8	0.95	0.88	41.8
9	0.8	0.98	39.2	9	0.95	0.88	41.8
10	0.8	0.98	39.2	10	0.95	0.88	41.8
11	0.8	0.98	39.2	11	0.95	0.88	41.8
12	0.8	0.98	39.2	12	0.95	0.88	41.8
13	0.8	0.98	39.2	13	0.95	0.88	41.8
14	0.8	0.98	39.2	14	0.95	0.88	41.8
15	0.8	0.98	39.2	15	0.95	0.88	41.8
16	0.8	0.98	39.2	16	0.95	0.88	41.8
17	0.8	0.98	39.2	17	0.95	0.88	41.8
18	0.8	0.98	39.2	18	0.95	0.88	41.8
19	0.8	0.98	39.2	19	0.95	0.88	41.8
20	0.8	0.98	39.2	20	0.95	0.88	41.8
21	0.8	0.98	39.2	21	0.95	0.88	41.8
22	0.8	0.98	39.2	22	0.95	0.88	41.8
23	0.8	0.98	39.2	23	0.95	0.88	41.8
24	0.8	0.98	39.2	24	0.95	0.88	41.8

Intermittent Renewable Resource					
ICAP	50.0	MW			
UCAP	14.0	MW			
Sample Days		Sample Days		Sample Days	
122	Adjustments	122	Adjustments	121	Adjustments
Hour	Production	Hour	Production	Hour	Production
1	0	1	0	1	0
2	0	2	0	2	0
3	0	3	0	3	0
4	0	4	0	4	0
5	0	5	0	5	0
6	0	6	5	6	0
7	5	7	10	7	5
8	15	8	20	8	15
9	25	9	30	9	25
10	35	10	40	10	35
11	40	11	45	11	40
12	50	12	50	12	47.5
13	47.5	13	50	13	47.5
14	42.5	14	50	14	35
15	35	15	40	15	25
16	20	16	30	16	15
17	5	17	15	17	5
18	0	18	5	18	0
19	0	19	0	19	0
20	0	20	0	20	0
21	0	21	0	21	0
22	0	22	0	22	0
23	0	23	0	23	0
24	0	24	0	24	0

Market Clearing Mechanism

- The market simultaneously clears the lowest cost set of resources that meet the BC and EC requirements in all hours and locations of the delivery year
- All qualified BC must submit an offer into the capacity market; qualified EC may submit an offer for emergency capacity
- Each capacity market offer is (UCAP MW, $/MW-day). The unit-specific UCAP offers are translated into a set of daily 24-hourly Adjusted ICAP schedules using the planning data from the reliability model
- We propose an hourly market clearing model uses core features of the DA market clearing model
- The market schedules capacity against the resource adequacy requirement expressed as hourly firm energy requirements subject to annual reliability targets to ensure that there is sufficient energy in each hour
- A resource needs a schedule in only one hour to clear a capacity commitment for the year; the highest cost resource cleared in any hour, sets the annual price for the market
- The transmission topology is reflected in the market using a (like the FTR model) N-0 planning model that reflects planned projects and known long-term transmission maintenance outages
- Cleared BC capacity take on a one-year obligation; cleared EC capacity can take on up to a three-year obligation

Market Clearing Mechanism: Example (structured to illustrate concept - no actual data, 1 of 2)

Assume a year with 5 hours,

Iteration 1

LOAD – INITIAL CONDITIONS

	BC req		EC req		
Hour	**Base load**	**Extreme Load**	**Diff**	**RM Base**	**RM Emergency**
1	800	850	50	0	0
2	700	740	40	0	0
3	650	670	20	0	0
4	900	938	38	0	0
5	1000	1060	60	0	0

Cleared BC

Cleared EC

Gens sorted based on offer price

PRELIMINARY CLEARING

Offered Capacity	ICAP	100	250	650	200	250	250	50	200	100	100
	UCAP	18	237	566	52	237	237	40	174	90	90
	Offer Price $/MW-day	$51	$55	$55	$60	$60	$64	$68	$70	$100	$110
	Base or Emergency	B	B	B	B	B	B	E	B	E	E
	Adjusted ICAP (expected production or availability)										
	Hour	**GEN 1**	**GEN 2**	**GEN3**	**GEN 4**	**GEN 5**	**GEN 6**	**GEN 7**	**GEN 8**	**GEN 9**	**GEN 10**
	1	0	240	580	90	240	240	40	190	90	90
	2	0	225	550	80	225	225	38	140	88	88
	3	30	230	580	50	230	230	40	180	90	90
	4	40	245	560	20	245	245	40	180	90	90
	5	20	245	560	20	245	245	40	180	90	90

Increase Reserve Margin on Base and Emergency by 30 MWs and 10 MWs

$LOLE_{modeled}$ = 0.12 days/year > $LOLE_{target}$

if $EUE_{modeled}$ = 20 MWh > EUE_{target} of 10 MWh

E(X) = expected value of X

Market Clearing Mechanism: Example (structured to illustrate concept - no actual data)

Assume a year with 5 hours,

Iteration 2 (Final)

LOAD – FINAL CONDITIONS

Hour	Base Load	Extreme load	Diff	RM Base	RM Emergency	Final BC req	Final EC req
1	800	850	50	30	10	830	60
2	700	740	40	30	10	730	50
3	650	670	20	30	10	680	30
4	900	938	38	30	10	930	48
5	1000	1060	60	30	10	1030	70

Cleared BC
Cleared EC
Gens sorted based on offer price

FINAL CLEARING

Offered Capacity	ICAP	100	250	650	200	250	250	50	200	100	100
	UCAP	18	237	566	52	237	237	40	174	90	90
	Offer Price $/MW-day	$51	$55	$55	$60	$60	$64	$68	$70	$100	$110
	Base or Emergency	B	B	B	B	B	B	E	B	E	E
	Adjusted ICAP (expected production or availability)										
	Hour	**GEN 1**	**GEN 2**	**GEN3**	**GEN 4**	**GEN 5**	**GEN 6**	**GEN 7**	**GEN 8**	**GEN 9**	**GEN 10**
	1	0	240	580	90	240	240	40	190	90	90
	2	0	225	550	80	225	225	38	140	88	88
	3	30	230	580	50	230	230	40	180	90	90
	4	40	245	560	20	245	245	40	180	90	90
	5	20	245	560	20	245	245	40	180	90	90

Requirements and market clearing complete
With BC at $60/MW-day and EC at $100/MW-day

$LOLE_{modeled}$ = 0.1 days/year <= $LOLE_{target}$
if $EUE_{modeled}$ = 10 MWh <= EUE_{target} of 10 MWh

Performance Assessments (1 of 2)

- Capacity performance means offering *Available ICAP* to the DAM and RTM and following PJM dispatch instructions
  - BC: offer available ICAP into the DA and RT markets in each hour; energy offers reflect variable operating costs.
  - EC: offer available ICAP into the DA and RT markets in each hour; energy offer is the greater of variable operating costs or $800/MWh.
- All capacity resources must submit compliant ancillary services offers in line with their capabilities
- BC and EC resources have performance measured in each hour of the delivery year
- BC and EC resources are paid for offered *Available ICAP* x the applicable hourly capacity rate
- BC and EC resources may, prior to the DA market offer deadline, assign qualified replacement UCAP to meet an obligation; commercial arrangements are bilateral
- FRR may use qualified UCAP from their owned or contracted asset portfolio that have not been assigned to a capacity obligation to cover a position short term or long term – arrangements must be made prior to the settlement period

Performance Assessments (2 of 2)

- A resource that correctly offers its Available ICAP but is not committed or dispatched by PJM is paid for its capacity – irrespective of system conditions
- PJM is responsible for scheduling resources. The portfolio of resources that PJM draws from are the capacity resources (both BC and EC) that it procures through the market and the assigned FRR resources. All qualified capacity offering into the market have limits on the way they can be used in operations, reflecting the physical attributes of each technology. PJM's operating schedules must reflect the physical limits on the qualified and cleared resources, including non-contract-related fuel access issues, start-times, and production profiles (for intermittent resources)
- If PJM determines EC resources are needed to address a likely reliability condition, posturing the resources, up to and including committing them to allow for securing multi-day fuel packages or long notification and start times, is appropriate
- If EC is unavailable at any time during a dispatch day when emergency conditions are declared, EC foregoes the hourly capacity payment and incurs a penalty calculated as 120 x the daily capacity payment (after 3 non-performance events, removed as EC for the balance of the delivery year)
- All non-performance or non-payments are allocated back to firm load

Resource Performance: Example (structured to illustrate concept - no actual data)

[1]	Case 1		Case 2	
Capacity type	BC	EC	BC	EC
ICAP_MW	75.0	75.0	75.0	75.0
UCAP_MW	67.5	74.3	67.5	74.3
Available_MW	67.5	74.3	60.0	74.3
$/MW-day [2]	100.0	185.0	100.0	185.0
$/MWh	4.17	7.71	4.17	7.71
Actual availability	90%	99%	80%	99%
Hours Available	7,884.0	8,672.4	7,008.0	8,672.4
EC days [3]		-		1
Raw Payment	2,217,375	4,963,594	1,752,000	4,963,594
Penalty	-	-	-	1,649,460
Final settlment	2,217,375	4,963,594	1,752,000	3,314,134
[1] Case 1 assumes that all parameters used to set UCAP equal actual values; Case 2 assumes BC availability is lower and there is 1 EC day				
[2] BC and EC clearing prices				
[3] EC days are those days with one or more hours of emergency conditions and the EC resource is unavailable				

Market Power Mitigation

Proposal

- All qualified BC must submit an offer into the capacity market; EC may submit an offer for emergency capacity
- Capacity offers are risk-adjusted going-forward costs less expected net energy and ancillary service revenue
- BC offers require no risk adjustment
- EC offers are exposed to penalty risk over multiple year commitment window; e.g., a Conditional Value at Risk (CVaR) construct would estimate the risk exposure
- As proposed, PJM is not obligated to purchase the entire EC requirement at one time and may prefer to procure in tranches; additionally, PJM may impose a budget constraint (like VRR) on EC procurement, limiting exposure to high costs

FRR Rule Changes

- FRR rules will be appropriately revised to reflect changes to requirements, modeling, accreditation, and testing
- For FRR, a penalty will apply to entities that do not provide the planned amount of capacity
- Assigned BC or EC resources that are not available at all (or most of the capacity commitment period) will be charged a penalty around 1.2 times the capacity clearing price reflecting replacement cost
- For EC, penalties for non-performance would be the equivalent of non-performance penalties for EC resources that cleared in the RPM, including, after three occurrences, being disqualified as EC
- FRR may use qualified UCAP from their owned or contracted asset portfolio that have not been assigned or available in the market without a capacity obligation to cover a position short term or long term – arrangements must be made prior to the settlement period