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Hedging Hourly Shaping Risks in Power Portfolio

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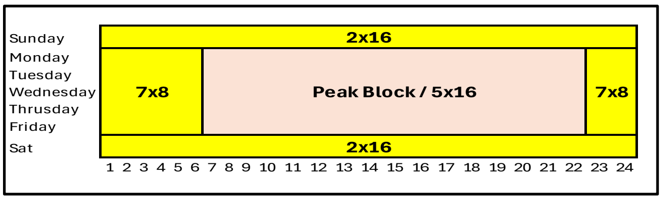
Abstract: There are several papers about forecasting electricity prices but most of the papers stop at forecasting monthly and block prices. This paper explores the Hourly Price and more specifically the Shaping Risks embedded within Power Portfolio. The paper describes the hourly shaping risks, limitations of hedging this risk and proposes a framework to hedge the Hourly Shaping Risks.

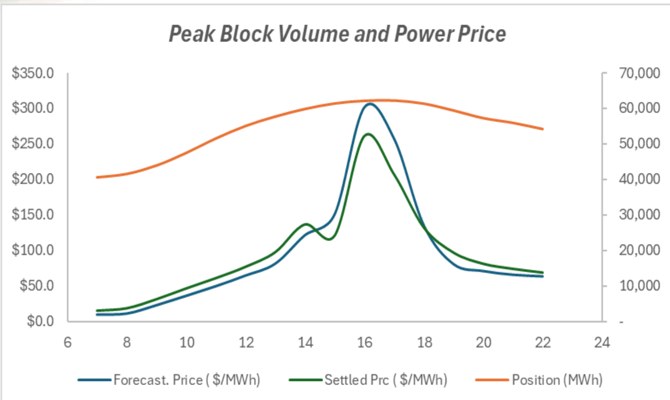
Keywords: *Shaping Risks, Power Hourly Price, Hedge, Simulation, Power Portfolio, Principal Component Analysis*

1. Background

There are several studies around forecasting power prices (Weron, 2014) but most of them stop at daily level (Cartea & Figueroa, 2007). Some of the studies have attempted to forecast at hourly prices (Mosbah & El-hawary, 2016) but these are for short periods only. A recent study was conducted to forecast hourly prices for longer term (Ziel & Steinert, 2018) but again they stop at price forecasting. This paper not only studies the risks associated with hourly shaping in a power portfolio but also devises a methodology for hedging that risks. In a few countries including United States, United Kingdom and Australia, the power is traded like any other financial instrument like equities and Fixed Income. There are several differences between the financial instruments and power though; Power is a Physical Product, it can't be stored, has limited liquidity and settles hourly but is traded in blocks. In most of the power markets, the instruments which are used to trade power are block products viz. 5x16, 2x16, 7x8 etc. Each of these blocks represents different hours of the week and when combined together they represent all hours in a week. These block prices are "Simple Average" of hourly price. In table below, the red color represents peak block and yellow represents WRAP block because it wraps around the peak block. The WRAP consists of 7x8 block and 2x16 block.



But the power settles at hourly granularity (or at 15-minute granularity). This discrepancy in granularity between settling (hourly) and trading (block) combined with different positions at each hour leads to shaping risks in power portfolio. Consider any power portfolio, whether it is Generation portfolio or Load portfolio or Physically Speculative portfolio and assume that it is fully hedged via block products; this portfolio is hedged at block level but has the risks at hourly level which can be called as " Hourly Shaping Risks" . If the price settles in such a fashion that block price is same (as the hedged price) but its shape is different then the portfolio will have an exposure to prices and thereby a P&L impact. The example below illustrates the impact of Hourly Shaping risks in a hypothetical power portfolio. The position and prices are just for one day. The blue line represents the forecasted shape while the green line represents the settled shape. The settled shape is flatter than the forecasted shape especially in the hours with highest load & price. Also, the position at each hour is different; it is much higher in super peak hours and relatively lower in Non-Super Peak hours. The forecasted margin using forecasted block price of $95.5/MWh is $90.2 M; But if the realized shape is flatter so that the average settled block price is the same i.e. $95.5, then the realized PnL is $89.2 M which is lower than the forecasted margin of $90.2 M.



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Hour	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22		
Position (MWh)	40,670	41,631	44,003	47,526	51,590	55,092	57,728	59,857	61,406	62,155	62,233	61,360	59,443	57,295	55,968	54,236	**AvgPrc**	**Total $**
Forecast. Price ($/MWh)	$10.1	$11.5	$23.3	$36.5	$50.1	$65.0	$81.6	$121.8	$151.2	$301.6	$257.3	$135.4	$81.0	$71.3	$66.1	$63.9	**$95.5**	
Forecasted PnL ($ Mil)	$0.4	$0.5	$1.0	$1.7	$2.6	$3.6	$4.7	$7.3	$9.3	$18.7	$16.0	$8.3	$4.8	$4.1	$3.7	$3.5		**$90.2**
Settled Prc ($/MWh)	$15.1	$18.5	$31.3	$46.5	$61.1	$77.0	$97.6	$136.8	$121.2	$261.6	$207.3	$132.4	$97.0	$81.3	$74.1	$68.9	**$95.5**	
Realized Pnl ($ Mil)	$0.6	$0.8	$1.4	$2.2	$3.2	$4.2	$5.6	$8.2	$7.4	$16.3	$12.9	$8.1	$5.8	$4.7	$4.1	$3.7		**$89.2**

Most of the portfolio owners are "Shape Takers" i.e. they don't do anything to take the position on the shape. There are primarily two reasons for this a) It is extremely difficult to estimate the shape based upon the forward block price b) There are no shape products that trade in the market. Even though some markets have some shape products, the liquidity is extremely low and/or Bid -Ask spread is very high.

2. *Drivers of Hourly shape*:

The hourly shape of the power price is stochastic and is a function of several real time parameters:

a. ***Load***: If the load spikes up especially in Super Peak hours, then in general price and thereby shape spikes up leading to shaping risks and vice versa.

b. ***Supply Stack***: Supply Stack can impact hourly shape in several ways:

i. If the supply stack consists of large generation units and if one of those trips, then more expensive units in supply stack have to come online leading to shape distortion.

ii. If supply stack a lot of Renew generation vix. Solar / Wind / Hydro/ Battery generation then it can impact hourly price. For example, if the wind or solar generation is below the expectation (p50) then more expensive units have to come online to meet the load obligation leading to shape distortion, Conversely, if there is a lot of Solar/Wind generation, then hourly prices in hours is much lower.

c. ***Transmission Infrastructure***: If the transmission infrastructure is not sufficient to transmit the power from source to sink then it leads to congestion in the sink. In such a scenario, the more expensive units have to come online to meet the load obligation leading to swings in hourly price in sink.

3. *Portfolio with large Shape Risks*

As show in example above, shape risks in present only in those portfolios where there is a shaped (non-uniform) volume and price for each hour. More specifically, if the portfolio has larger volume at high priced hours, then there is substantial shaping risks. Given this and the factors that impact the hourly shape, following portfolio will have the significant shaping risks:

- Geographical Location: If the portfolio is for a geographical region which witnesses extreme temperatures. This is more evident in Summer and Winter months when temperatures can swing a lot leading to large variation in load and thereby price.
- ISOs which have old and large generation units: Such generation units are more susceptible to unplanned outage forcing an expensive unit to come online and leading in price spikes.
- ISOs which have large renewable penetration: In such ISOs, the bottom of the stack is comprised of renewable units and if they fail to operate in real time / or generate more than expected power then it distorts the price shape. Because of the RPS mandate of each state and because of carbon footprint reduction target by Federal government, the proportion of renew generation has been increasing at a rapid pace in most of the ISOs. As this proportion increases, the real time shape of hourly prices has been changing. Within United States, CA has been leading this effort and has a fairly large renew penetration. In CA, we see a "Duck Shaped" curve and it is driven by Solar Generation viz. the prices are relatively higher in morning when there is no sunshine (Neck of the Duck), prices drop sharply as sunshine increases and Solar generation comes online (Belly of the Duck) and prices again spike up later in the day when sun goes down (tail of the duck).
- ISOs which don't have adequate transmission capabilities.
- ISOs which have lower reserve margin
- ISOs which don't have capacity prices: In such an ISO, then generations rely on price spikes to stay afloat and the proportion of expensive units in such ISOs is larger.

4. *Method/ Model to Hedge Shaping Risks:*

This paper employs Principal Component Analysis framework for hedging the shaping risks. Shape within a Peak block can be considered as a 16-dimensional problem wherein each of those 16 hours represents a dimension. By using PCA, the dimensions can be reduced to one to two dimensions (Kambhatla & Leen, 1997) and then they are easier to hedge. The model consists of two major steps i) Simulate Shape ii) Hedge Shape.

a. **Simulate Hourly Shape**:

We observe block prices in the market, and we can use this to imply the hourly shape from these market quotes. This is a three-step process:

i. Simulate the Forward Monthly Price: There is a lot of literature (Suganthi & Jayalalitha, 2019) on this and the forward GBM formula wherein the drift is zero can be used to simulate the forward monthly block prices say ***M*** times.

ii. Simulate the Daily Price: Each of the above simulations of the forward monthly price, is simulated ***N*** times at daily level. In order to do so, first the characteristics of the daily price is determined. In a given market, the daily price can exhibit several characteristics including mean reversion, jump diffusion, negative price (Mayer, 2012). Depending upon the price characteristics, an appropriate model is chosen, and it is used in conjunction with forward block prices to simulate the daily price.

iii. Shape Library: The shape library as the name suggests is nothing but a shape repository. A good place to constructing the shape library is historical data; it is considered a good source because historical data has all sorts of "shape drivers" baked into them including variation in load, Generation outage, different levels of renew generation, congestion etc. While selecting historical data, we have to be careful not to go far in the past because there could be changes in supply stack and transmission infrastructure between the projected period and historical period. If there are major changes between historical period and projected period, the shapes have to be altered / calibrated to changing situations.

iv. Simulate Hourly Price: Once the daily power and gas prices have been simulated, the daily heat rate can be determined. Daily heat rate is a proxy for the load, and it can be used to determine the shape. But the relation between daily heat rate and hourly shape is not deterministic; for a given daily heat rate, there can be many possible values of hourly shape. Again, a stochastic model can be used to determine the hourly shape using the shape library.

b. ***Hedge Variation:*** At the end of the previous step we have ***MxN*** hourly price shape simulations. The correlation matrix of the shape simulation is computed and PCA is employed to compute PC1 , PC2 …PC16; PC1 represents the maximum variation in the P&L and if PC1 can he hedged then most of the variation in shaping risks can be hedged. So the over-arching approach here is not to forecast the shape for each hour "most accurately" but rather to capture the variation in shapes and then hedge this variation. An appropriate hedge instrument is chosen which is correlated with PC1.

5. Data

For the purposes of this study ERCOT market was chosen. ERCOT has been chosen because summer months in ERCOT region can get pretty hot and historically we have seen multiple price spike reaching the cap levels of $5000 in super peak hours. Also, ERCOT has a large renew generation, lower reserve margin, doesn't have capacity prices mechanism and we witness a lot of congestion between source zone (most of renew generation is located in West Zone) and sink zone (most of the load is located in North and Houston Zones).

ERCOT Summers months span from June through September but for purposes of this study, only July and August were used. Historically the price spikes have happened during 2x16 block also, for purposes of this study, it has been assumed that price spikes will happen only during weekdays, so 5x16 block has been considered. The historical shapes from 2014 through 2016 has been used for shape simulation. The study year is 2017 viz. shapes were simulated, hedged and back tested for July and August of 2017.

The observation point is three months prior to delivery i.e. April of the given year. This timeframe has been chosen because by this time, the market has a fairly good estimation of how summer will pan out; we can use the information from block products and the options on these products to better simulate the forward month block prices. Also, temperature in July & August months are "somewhat" correlated with temperature in March & April and as these months roll-off, market can estimate as to how the summers prices will realize. The market also has a better estimate of supply stack and any transmission upgrades by this time. The portfolio is composed of Load in Houston Zone and is assumed to be fully hedged using 5x16 block products.

6. Results

The correlation matrix for July 2017 and August 2017 hourly shapes is as follows. As shown in tables below, the hours 15 through 17 contribute the most to PC1. Also PC1 represents most of the vaiation. Portfolio manager hedged the portfolio on March 31st 2017 and at this point there was a shape. The realized shapes declined, and the portfolio had a shaping risks is ($16.2) M. But the hedges made money in the amount of $10.9 M. So, the hedge not only moved opposite to native position but also offsets about 67% of the shaping loss.

PCA analysis for July 2017

	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10	PC11	PC12	PC13	PC14	PC15	PC16
HR7	(0.126)	(0.017)	0.059	0.219	0.170	(0.194)	0.244	0.108	(0.218)	(0.032)	0.072	(0.334)	0.547	0.183	0.485	(0.250)
HR8	(0.133)	(0.015)	0.042	0.193	0.113	(0.219)	0.160	0.127	(0.185)	(0.174)	0.293	(0.032)	0.142	(0.417)	(0.657)	(0.250)
HR9	(0.130)	(0.008)	(0.074)	0.235	0.105	(0.230)	0.064	0.100	(0.087)	0.085	0.166	0.108	(0.472)	0.693	(0.156)	(0.250)
HR10	(0.127)	(0.014)	(0.031)	0.233	0.064	(0.187)	0.093	0.072	(0.007)	(0.015)	(0.047)	0.413	(0.392)	(0.495)	0.492	(0.250)
HR11	(0.117)	(0.011)	(0.129)	0.214	(0.078)	(0.156)	(0.014)	(0.165)	0.145	(0.127)	(0.837)	0.009	0.130	0.060	(0.214)	(0.250)
HR12	(0.133)	0.010	(0.139)	0.067	(0.268)	0.048	(0.289)	(0.062)	0.507	(0.582)	0.313	(0.159)	(0.003)	0.048	0.115	(0.250)
HR13	(0.127)	(0.065)	(0.147)	(0.147)	(0.465)	0.050	(0.483)	0.459	(0.418)	0.166	(0.066)	(0.011)	0.054	(0.029)	0.019	(0.250)
HR14	(0.118)	(0.110)	(0.380)	(0.588)	(0.264)	(0.138)	0.471	(0.311)	(0.057)	0.058	0.079	0.008	(0.020)	(0.004)	0.014	(0.250)
HR15	0.364	(0.627)	0.185	(0.256)	0.312	(0.297)	(0.334)	(0.107)	0.049	(0.002)	(0.005)	(0.025)	(0.004)	(0.010)	0.015	(0.250)
HR16	0.648	(0.093)	(0.443)	0.264	0.013	0.417	0.209	0.154	(0.008)	(0.003)	0.014	(0.001)	0.012	(0.012)	(0.021)	(0.250)
HR17	0.515	0.557	0.390	(0.079)	(0.301)	(0.314)	0.004	(0.108)	(0.039)	(0.008)	0.014	0.021	(0.012)	0.022	0.015	(0.250)
HR18	(0.075)	0.512	(0.281)	(0.348)	0.618	0.085	(0.258)	0.079	0.041	0.019	(0.049)	(0.040)	0.005	(0.039)	(0.002)	(0.250)
HR19	(0.098)	(0.085)	0.444	(0.274)	0.008	0.268	0.345	0.541	0.371	0.020	(0.143)	0.005	(0.048)	0.043	(0.047)	(0.250)
HR20	(0.108)	(0.034)	0.335	(0.024)	0.063	0.523	(0.004)	(0.379)	(0.481)	(0.319)	(0.070)	(0.083)	(0.209)	0.024	0.027	(0.250)
HR21	(0.116)	(0.005)	0.104	0.088	(0.022)	0.228	(0.124)	(0.256)	0.148	0.292	0.192	0.636	0.452	0.129	(0.057)	(0.250)
HR22	(0.117)	0.007	0.064	0.204	(0.070)	0.115	(0.085)	(0.252)	0.239	0.622	0.075	(0.516)	(0.184)	(0.196)	(0.026)	(0.250)

PCA analysis for August 2017

	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10	PC11	PC12	PC13	PC14	PC15	PC16
HR7	(0.101)	0.101	(0.060)	(0.072)	0.292	(0.040)	0.269	0.194	(0.192)	(0.235)	(0.457)	0.491	(0.284)	0.159	(0.251)	0.249
HR8	(0.102)	0.088	(0.071)	(0.060)	0.311	(0.066)	0.166	0.131	(0.324)	0.071	0.169	0.101	0.191	(0.210)	0.732	0.250
HR9	(0.108)	0.089	(0.052)	(0.046)	0.274	(0.087)	0.167	0.100	(0.182)	0.155	0.419	(0.179)	0.201	(0.331)	(0.615)	0.250
HR10	(0.116)	0.074	(0.033)	(0.016)	0.251	(0.155)	(0.007)	0.000	0.219	0.287	0.207	(0.153)	0.003	0.795	0.036	0.252
HR11	(0.123)	0.088	0.026	(0.026)	0.203	(0.220)	(0.023)	(0.247)	0.294	0.168	(0.622)	(0.417)	0.096	(0.274)	0.042	0.250
HR12	(0.133)	0.072	0.027	(0.053)	0.063	(0.031)	(0.266)	(0.233)	0.581	(0.149)	0.246	0.552	0.131	(0.198)	0.006	0.249
HR13	(0.132)	0.083	0.102	(0.084)	(0.075)	(0.024)	(0.371)	(0.592)	(0.524)	(0.309)	0.037	(0.085)	(0.009)	0.144	(0.046)	0.250
HR14	(0.111)	(0.048)	0.438	(0.062)	(0.557)	(0.550)	0.300	0.127	0.008	(0.043)	0.063	0.025	(0.017)	(0.002)	0.032	0.250
HR15	0.048	(0.729)	0.477	0.170	0.219	0.306	0.025	(0.027)	(0.010)	0.056	(0.023)	0.012	0.014	0.001	(0.007)	0.250
HR16	0.592	(0.283)	(0.283)	(0.629)	(0.053)	(0.124)	(0.096)	0.047	0.020	(0.028)	(0.006)	(0.033)	(0.001)	(0.000)	(0.005)	0.250
HR17	0.694	0.462	0.280	0.379	0.030	0.108	0.065	(0.053)	0.012	0.007	0.013	0.013	0.005	0.004	0.005	0.250
HR18	0.057	(0.296)	(0.540)	0.629	(0.154)	(0.299)	(0.176)	0.070	(0.074)	(0.013)	(0.030)	0.050	0.012	(0.020)	(0.017)	0.250
HR19	(0.091)	(0.017)	(0.321)	0.006	(0.263)	0.427	0.614	(0.326)	0.166	(0.174)	0.083	(0.143)	(0.038)	0.033	0.054	0.251
HR20	(0.120)	0.117	(0.038)	(0.096)	(0.402)	0.361	(0.185)	0.088	(0.170)	0.626	(0.205)	0.252	0.184	0.010	(0.067)	0.250
HR21	(0.133)	0.111	0.035	(0.017)	(0.106)	0.266	(0.250)	0.543	0.101	(0.502)	(0.080)	(0.280)	0.332	0.093	0.004	0.250
HR22	(0.120)	0.089	0.012	(0.023)	(0.034)	0.128	(0.234)	0.181	0.075	0.083	0.184	(0.201)	(0.819)	(0.209)	0.097	0.250

	Shape Impact	Hedge Impact
8/1/2017	($762,485)	$379,522
8/2/2017	($823,706)	$525,012
8/3/2017	($473,264)	$496,345
8/4/2017	($1,080,476)	$733,030
8/7/2017	($2,856,419)	$1,896,580
8/8/2017	($958,875)	$797,782
8/9/2017	$411,471	($462,844)
8/10/2017	($1,008,233)	$625,239
8/11/2017	($1,544,498)	$1,068,612
8/14/2017	($396,895)	$351,768
8/15/2017	($439,183)	$281,829
8/16/2017	($372,392)	$318,870
8/17/2017	($497,078)	$333,644
8/18/2017	($426,121)	$312,662
8/21/2017	($511,482)	$349,426
8/22/2017	($455,499)	$302,021
8/23/2017	($532,835)	$316,773
8/24/2017	($463,107)	$329,661
8/25/2017	($601,863)	$411,578
8/28/2017	($834,618)	$521,484
8/29/2017	($586,706)	$356,052
8/30/2017	($551,536)	$365,241
8/31/2017	($462,735)	$328,042
Total	**($16,228,535)**	**$10,938,330**

7. Conclusion

The framework of Principal Component Analysis was employed to compute the variation in Shaping Risks and it was successfully used to hedge the Shaping Risks for Power portfolio for Summer 2017 delivery in ERCOT market. This methodology proves the hypothesis that since hourly shape is purely stochastic, in order to hedge it, we needn't forecast it accurately. As long as we can forecast the variation and hedge the PC1, we can hedge the majority of the shaping risks. One of the critical assumptions of this model is that correlation between the 16 hours should hold true. Since the power price are primarily driven by load and since load at each hour is highly correlated, it implies that the correlation between prices will hold true in all conditions.

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