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Forecasting capacity price in CA power market (CAISO)

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Abstract
There have been several studies about modelling prices in various ISOs but most of them are concentrated to Power Price. There are a couple of papers about forecasting capacity prices but they study long term capacity prices. This paper studies the behavior of capacity prices in electricity markets and develops a model to forecast capacity price in short term and medium term in California market (CAISO).

Keywords: Capacity prices, reserve adequacy, electricity market, CAISO

Introduction

Almost all electricity markets within United States have something called as "Capacity" market" addition to Energy market and there has been several studies about forecasting energy prices (Weron, 2014) [1]. For energy and ancillary markets, the generators are paid by ISO when they generate and dispatch electricity to grid but capacity market is different. As the name suggests, the generators are paid "Capacity price "just to make their capacity available to the grid. The other key difference between capacity and energy payment is "Type of Payment". Energy is a variable payment and is a function of how much of MWs is dispatched to grid while capacity is a fixed payment and is only a function of nameplate capacity of the generation plant.

There are two primary objectives of capacity market 1) Grid Reliability vis a vis Reserve Margin (McCullough, Weisdorf, Absar, 2020) [2]: Energy payment is a function of energy generated which in turn is a function of energy price. Since energy price is highly volatile and cyclical in nature, often times the generators realize negative returns on their investment and are forced to shut down. But, if there is also a "capacity market" then generators are paid capacity price in addition to energy price and this is sufficient to make them whole. In such markets, there is enough generation capacity and thereby higher reserve margins which ensures grid reliability 2) Long term price signals: Capacity price sends long term price signals to market participants and this in turn enables generators to make long term investment decisions.

In most of the markets, the generators are paid the capacity revenue by the ISO. Since the ISO is a non-profit entity, the ISO generates this capacity revenue through load serving entities. All load serving entities are required to procure "capacity" for every MWs of load they serve and the load serving entities in turn generate these dollars from end consumers.

Different markets have different capacity market constructs. In ISOs such as PJM, NY, NE and MISO, an auction is conducted by the ISO. The generators participate in this auction and are awarded MWs at the auction cleared price. While in other markets, like in CA, capacity market is bilateral market and different market participants are supposed to meet their capacity obligation through bilateral trades. In some markets, the unit of capacity is MW-Day while in others it is KW-Month. In order to avoid the misuse of this market, some markets have introduced a concept of Capacity Penalty. If a generator has been awarded a capacity payment but it fails to perform in extreme weather events, then ISO has the right to levy a penalty on the generators. The formulae for computing the penalty is different across the ISOs but the idea is the same *viz.* to hold the generators accountable for performance.

As the proportion of Solar, Wind and Battery generators increase in ISOs, a new concept has been introduced called as "Effective Load Carrying Capacity" (ELCC). It is a function of technology of plant and essentially measures how effective a given plant is, to serve the incremental MW in case of large load demand. This ELCC curve along with nameplate capacity of plant, is used to determine the capacity payment to generators. E.g. In some ISOs, the peak load is witnessed between 6:00 PM to 8:00 PM; in these hours of the day, there is no solar generation and Solar plants can't serve an increase in load. Hence the ELCC curve for Solar Generators is less than 100%. Batteries have slightly different reason; most of the batteries are either 2 hours or 4 hours. If the load demand persists for more than 4 hours, then the battery can't serve this load and hence their ELCC is also less than 100%.

No matter whatever is the construct of the capacity curve, most of the markets are highly illiquid. In PJM market, there is a Base Residual auction that happens three years in advance and as we move closer to delivery, there are incremental auctions. So there are four trading opportunities and there is one counterparty, the ISO. The MISO market has similar construction, a Base auction, followed by incremental auctions. The capacity market in NY is relatively more liquid and one can observe daily quotes through brokers. In CA ISO, this market is called as Resource Adequacy (RA) and is a bilateral market (Pfeifenberger, Spees, Newell, 2012) [3]. In CA, the load serving entities are required to submit their capacity plan by October 1st of every year for following year. If load serving entities have to make changes to their plan after October 1st, then they have until end of year i.e. December 31st to submit those changes. After this time also, the load serving entities have time until first of delivery month to transact capacity. This usually happens if a generator anticipates that it would experience outage of its fleet so it needs to buy back capacity in cover its short position. Similarly, if the load serving entity has acquired a load book, then it leads to an increased capacity need. But all these trades are Bi-lateral and there is no market per-se. Even though the broker quotes are available but the price discovery mechanism is not robust. Additionally, most of the liquidity is in prompt year and tapers off for outer years.

In all markets, the long term capacity price is determined through a fundamental analysis. If we set up a coal or a gas plant today, then it has to breakeven the investment over its lifetime of the plant, say 30 years. The cost for such an investment is the capital cost, fuel cost, operational cost etc. while the revenue consists of energy, ancillary and capacity payments. The forward curve for energy is observed for outer years and it can be used to estimate energy revenue. And any shortall between energy payment and cost is used to determine the capacity curve. This capacity payment to generators ensures that new investment in coal / gas plants are zero NPV project and guarantees them a threshold return. The capacity prices determined using this methodology are "Long Term price signals" and is extensively used by market participants. But these Long term capacity prices are deterministic in nature.

The above methodology is good for long term but there is no such methodology for short term to medium term delivery. The scope of this paper is to develop a model which can forecast capacity prices in short term and medium term.

Model

In order to determine an appropriate model for forecasting capacity price, the historical forward price is plotted. As shown in graphs below, the monthly capacity prices depict jump characteristics.

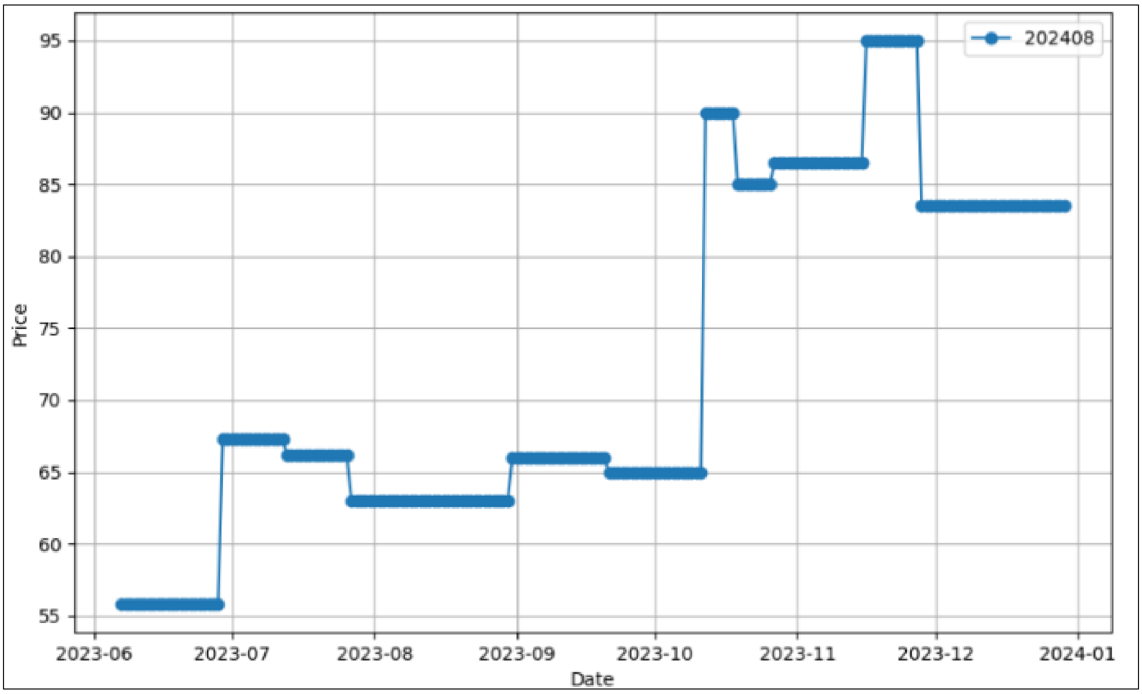

Fig 1: Price over time for 202408

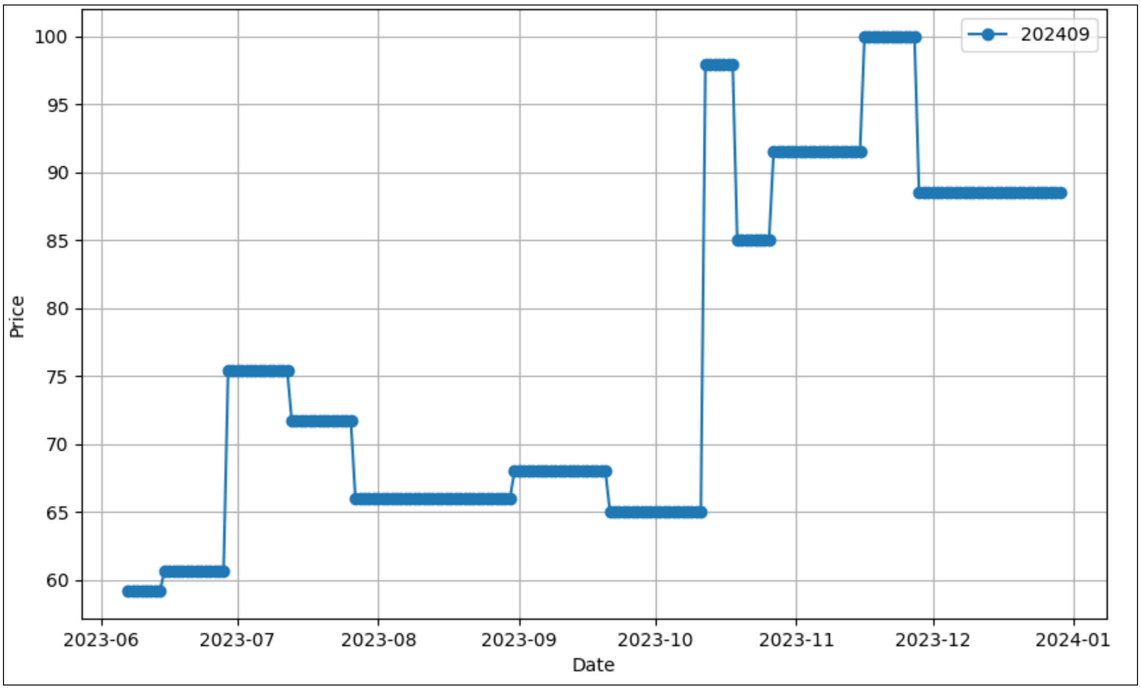

Fig 2: Price over time for 202409

There are a couple of ways to model jump but Poisson Process is the best amongst them (Song, Handong, 2023) [4]. Per the Poisson process, the Probability of jump is given by following formula where Lambda (ʎ) is the mean arrival rate and K is the numbers of jumps in a given time interval:

$$\Pr(X=k) = \frac{\lambda^k e^{-\lambda}}{k!},$$

Besides this, characteristics of Poisson process match very closely with ones depicted by capacity price. Capacity prices have discrete jumps and the jumps between two time intervals are independent of each other. Also, the Probability of jump is a dependent upon length of time intervals; as time tends to zero, the Probability of jump approaches to zero. Lastly, in a given time interval either a jump occurs or it doesn't.

The second challenge is to model the jump size. A plot of historical jumps shows that 1) jumps can be both positive and negative 2) the jump distribution have fat fails. Given this, the lognormal distribution and normal distributions can be ruled out. Also, since the distribution has fat tails, t distribution can be used for modelling jumps

Data

Within CAISO, the CA System capacity curve has been chosen. In CAISO, the third quarter is the most interesting quarter because 1) in this quarter, the water in the dam has been depleted and so the supply stack excludes hydro generation 2) third quarter witnesses large load, it being a summer season in CA 3) capacity and energy prices are the highest and most volatile for this quarter. Given this, Q3 of 2024 was chosen for this study. Also, as stated earlier in the paper, since most of the transactions for a given year, takes place in Jun through Dec of prior year, the observation period is Jun 2022 through Dec 2022. Lastly, the price for each month of quarter has been modelled separately. The testing period is from Jan 2024 trough April of 2024. The granularity of price quotes is weekly i.e. price quote is available once a week.

Results

The lambda for July 2024 - September 2024 was computed from historical data and is summarized in table below. The mean arrival rate for the these months is between 0.33 and 0.37. For the three months, the Probability of zero jump is highest at around 70%, the Probability of 1 jump is around 25% and Probability of 2 or more jumps is very low. It has been assumed here that more than 1 jump doesn't occur.

Table 1: Summary of Jump Probabilities and Lambda Values

	Jul-21	Aug-24	Sep-24
Lambda (λ)	0.33	0.33	0.37
Ftobatility of zero jump	71.7%	71.7%	69.3%
Ftobatility of One jump	23.9%	23.9%	25.4%
Probability of Two jumps	4.0%	4.0%	4.7%
Probability three jumps	0.4%	0.4%	0.6%

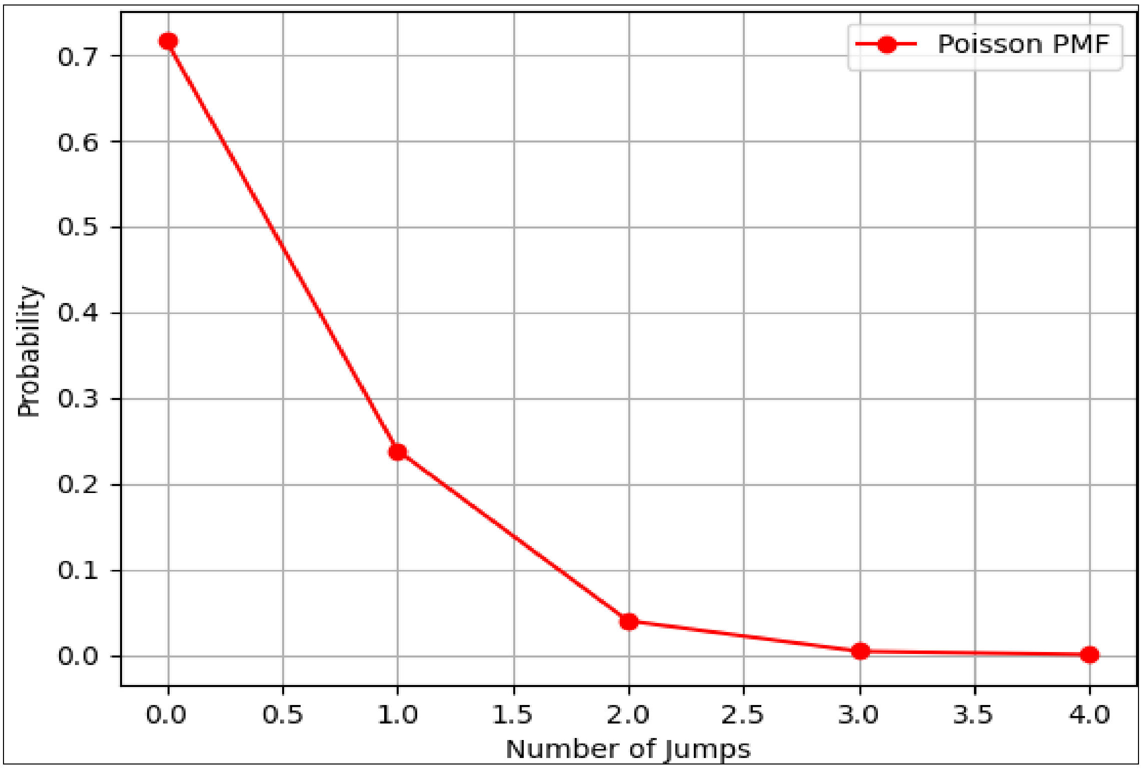

Fig 3: Poisson distribution (Lambda =0.33) for delivery month 202407

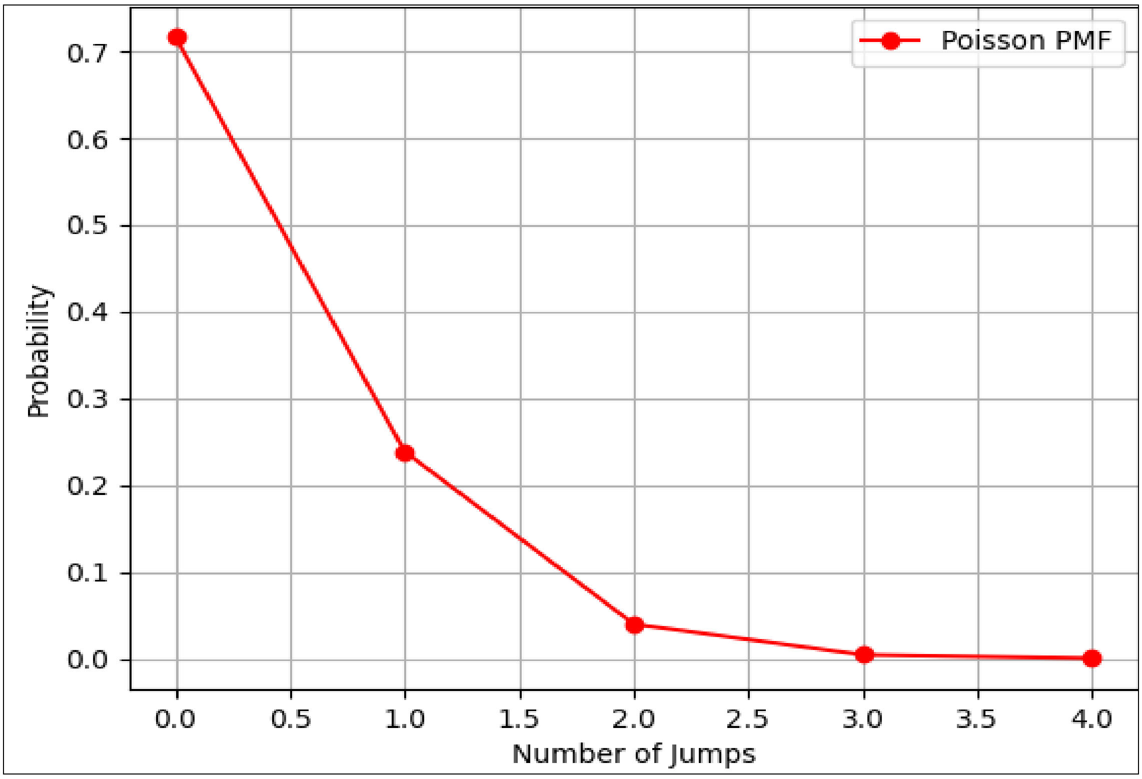

Fig 4: Poisson distribution (Lambda =0.33) for delivery month 202408

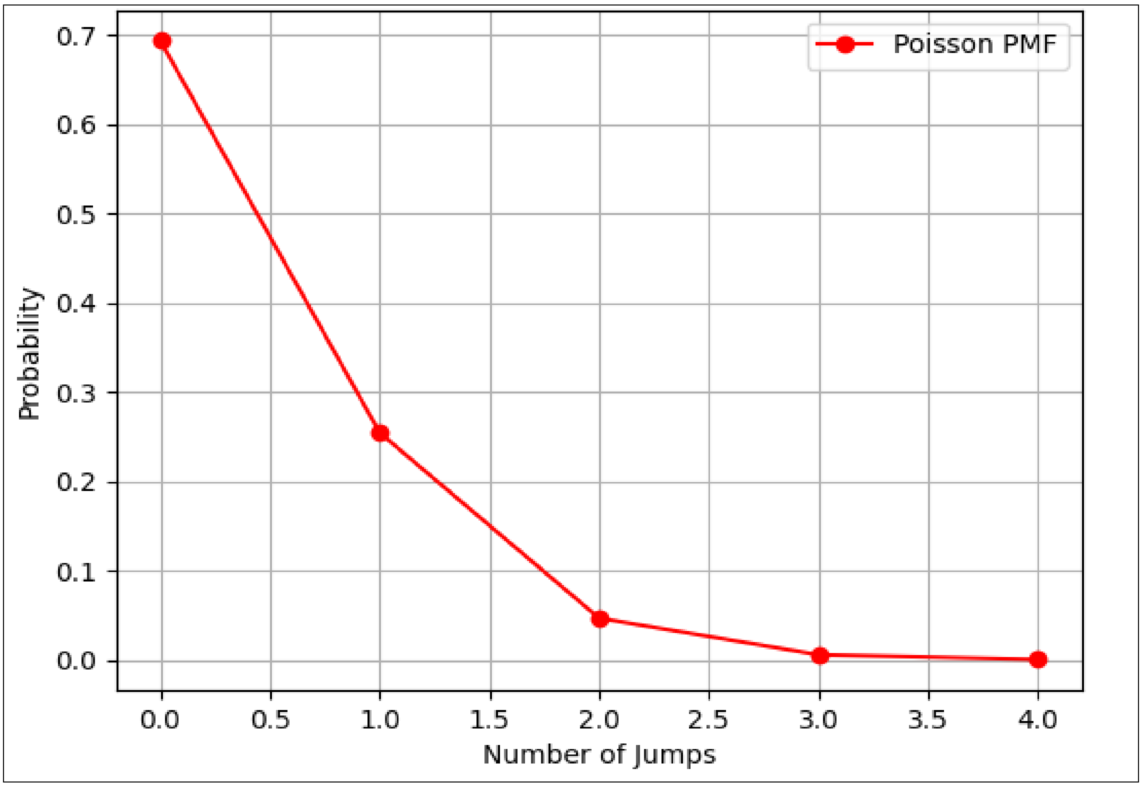

Fig 5: Poisson distribution (Lambda =0.37) for delivery month 202409

The jump size have been fitted into t distribution and parameters of t distribution is as follows:

Table 2: Fitted Parameters of T Distribution for Jump Sizes

	Jul-24	Aug-24	Sep-24
Degrees of Freedom	1.72	3.57	4.02
Mean	2.07	1.14	0.72
Standard Deviation	5.95	7.06	9.36

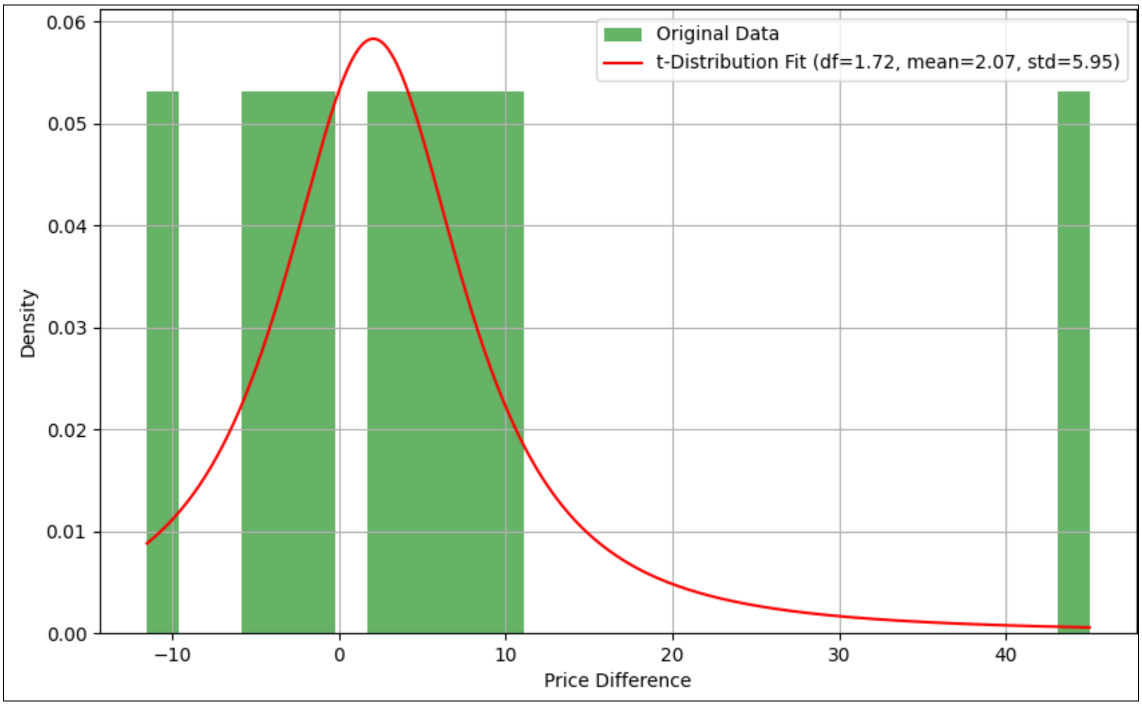

Fig 6: T-distribution fit for delivery month 202407

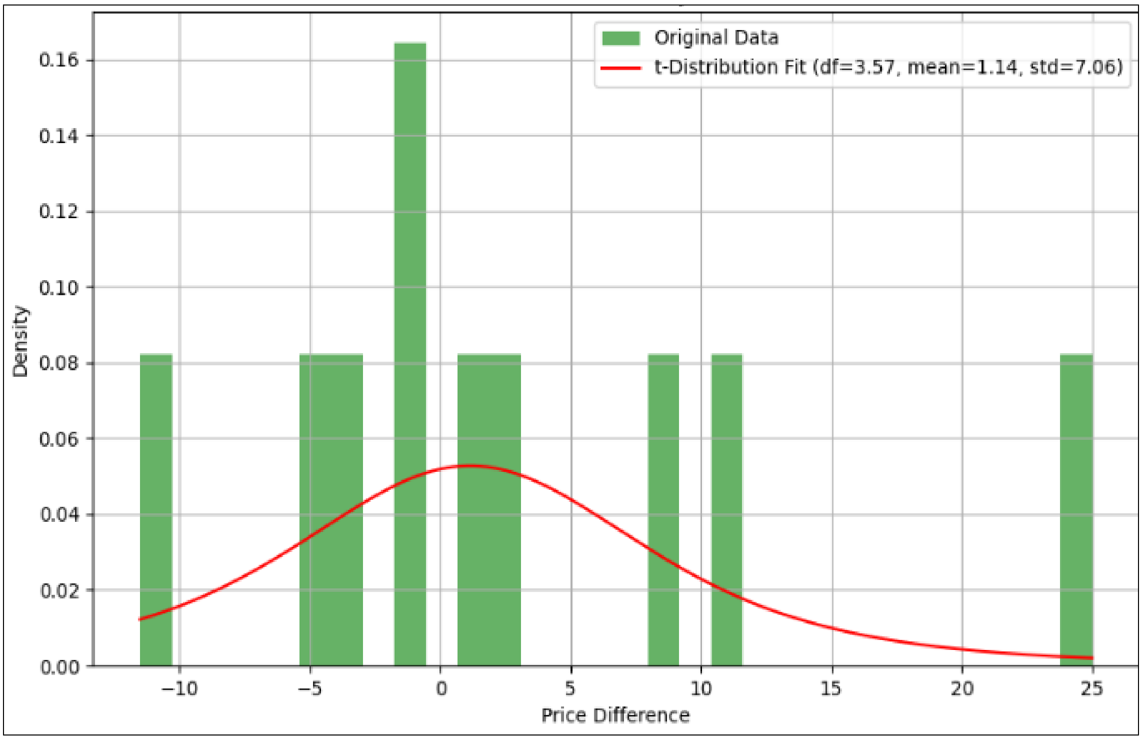

Fig 7: T-distribution fit for delivery month 202408

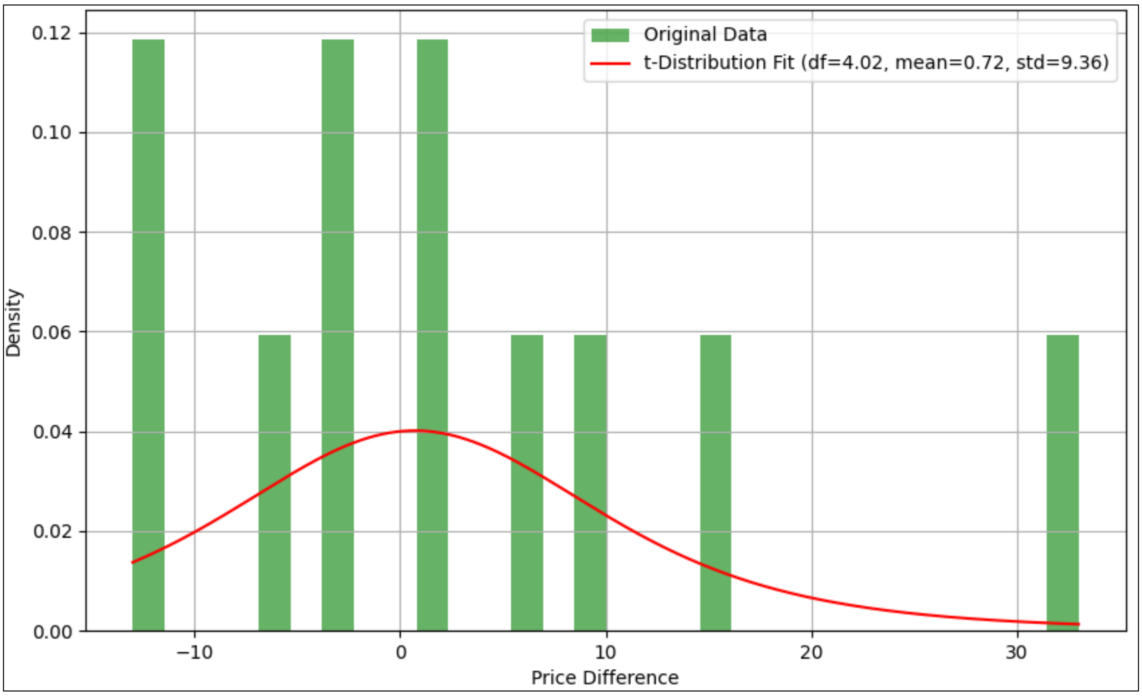

Fig 8: T-distribution fit for delivery month 202409

Using these parameters, the capacity prices for these months are simulated 100 times and plotted in graphs below. As shown in graphs below, the simulated paths follow the jump process and is very similar to paths of capacity price. Also, as time horizon increases, the cone of possibility increases because of extrinsic / time value of the capacity prices. The black line the graphs, is the observed forward price in the market and is well within the upper and lower bounds of simulated prices. The prices can be simulated 1000 times and it can be used to compute p5 and p95 values.

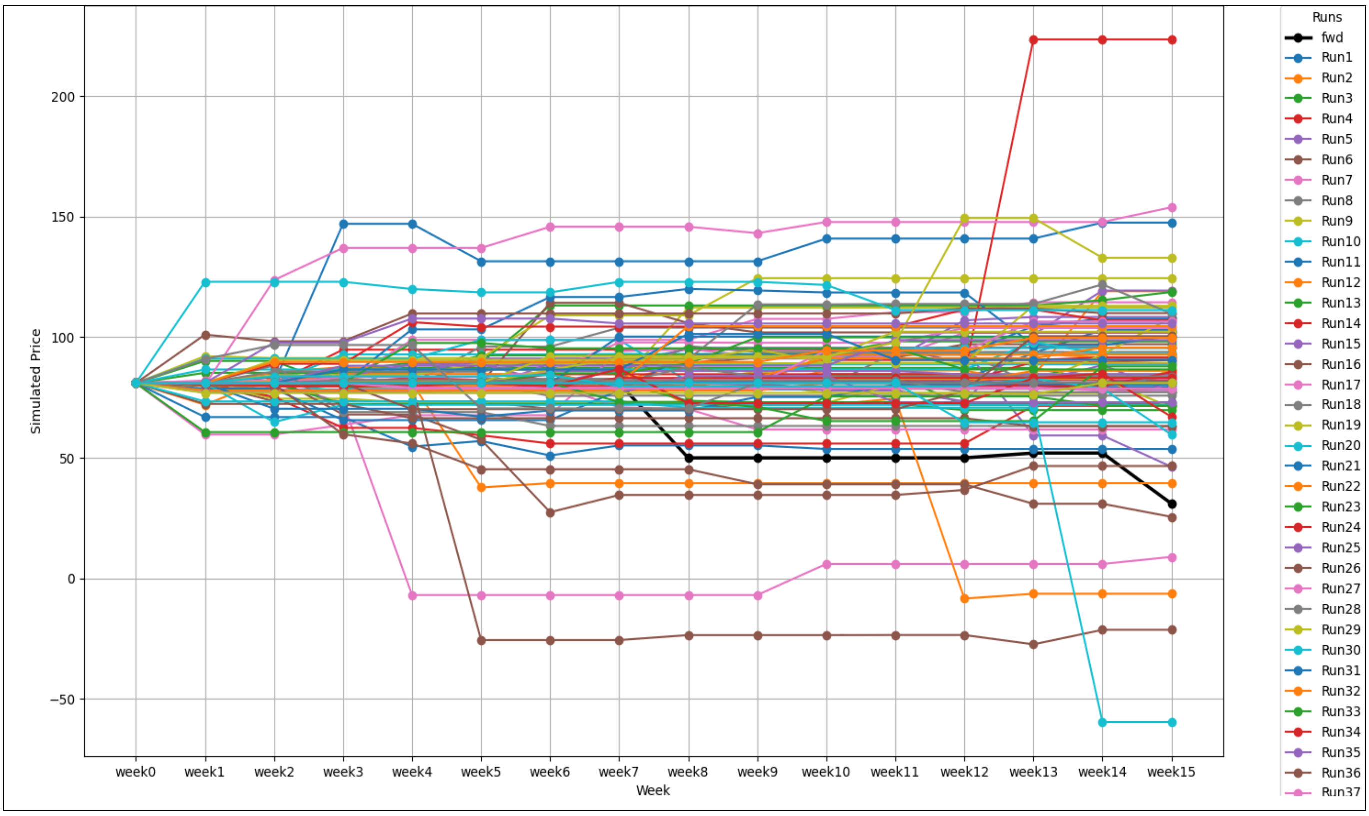

Fig 9: Price simulation over time for simulated price comparison 202407_100_t

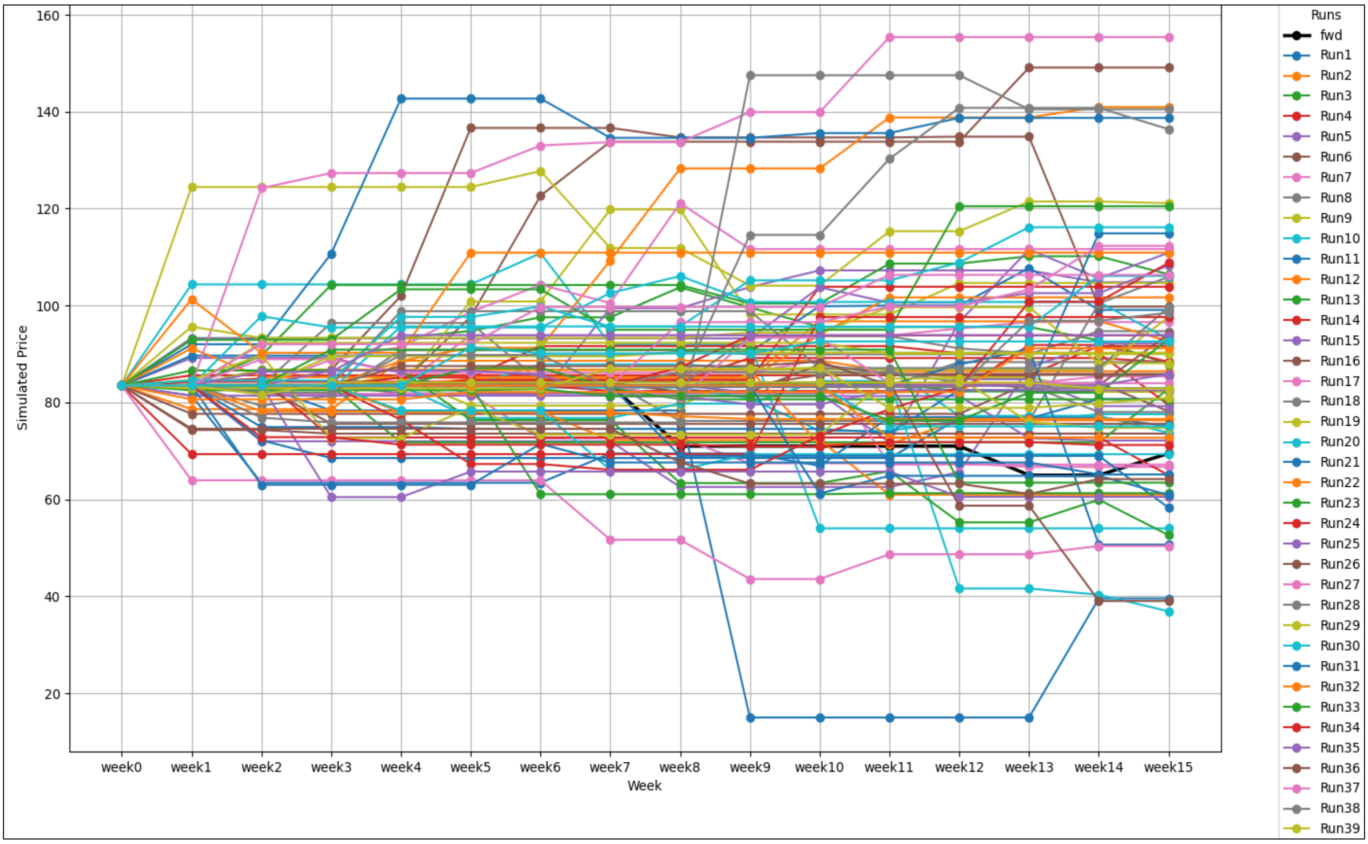

Fig 10: Price simulation over time for simulated price comparison 202408_100_t

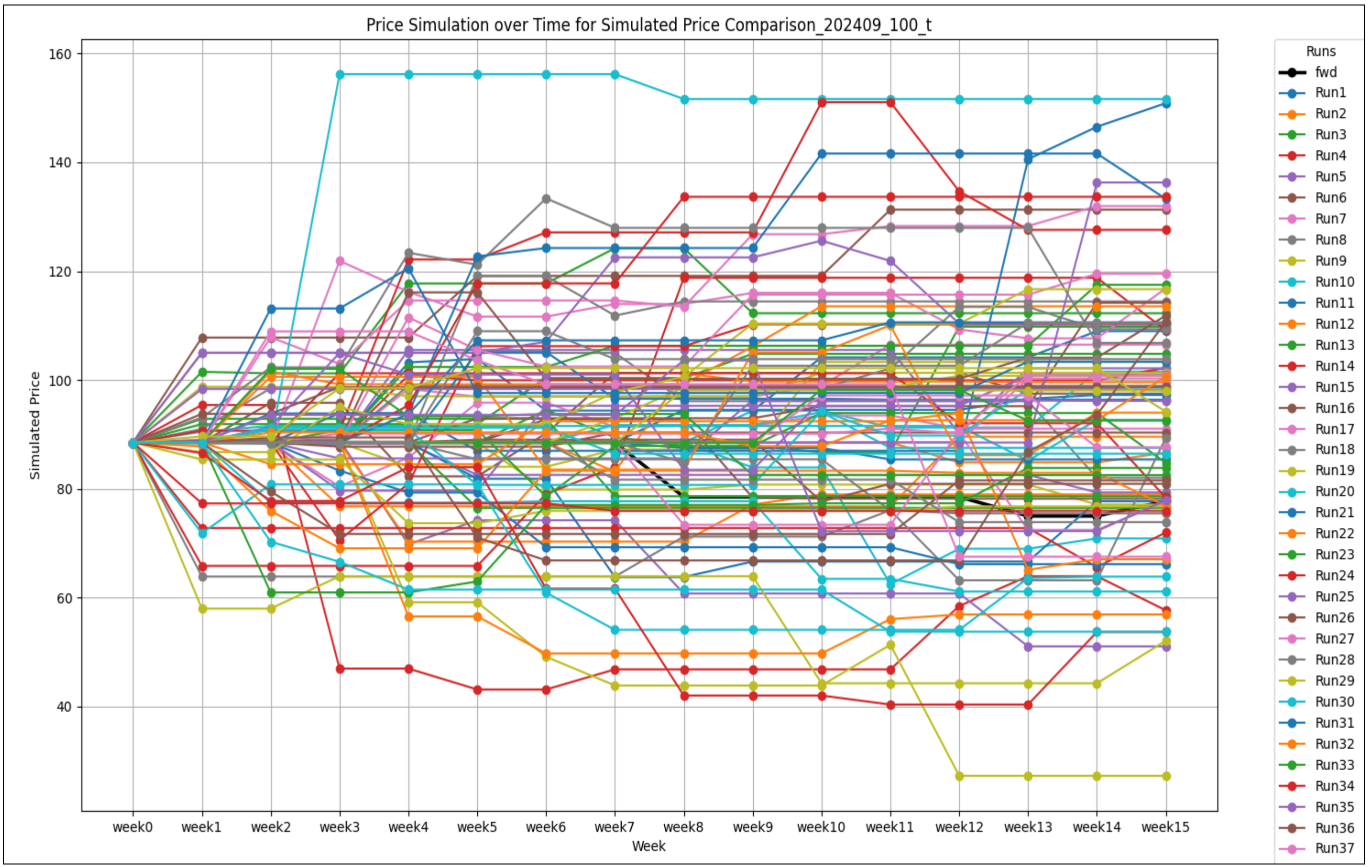

Fig 11: Price simulation over time for simulated price comparison 202409_100_t

Conclusion

There are several challenges with projecting capacity prices like highly illiquid, deterministic in long term and yet stochastic in shorter term. But it is possible to model the capacity prices in short to medium term through a jump process and t distribution. The output from this model can be used by traders to take position. It can also be used by risk team to determine the extreme value like p5 and p95. Like all models, this capacity model also has limitations. The model is based upon broker quotes and so the model is as good as the broker quotes. The model is based quotes during the most liquid period between Jun through Dec of prior year for next year delivery. As we get closer to delivery, the volume of transaction decreases substantially and the price is not representative of all volumes transacted for the delivery.

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