

# Assessment of Price Risk of Power under Indian Electricity Market

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## ABSTRACT

Abstract: In order to promote competition in Indian Electricity Market as per Indian Electricity Act 2003, Power Exchanges are established and running successfully since 2008. Power exchange is an electronic exchange which provides a common place for electricity trading. Price of electricity is more volatile than any other commodity. This volatile nature of electricity-price introduces risk to market participants. Hence assessment and control of risk have become essential tasks for the players in power market. In this paper Value at Risk (VaR) & Conditional Value at Risk (CVaR) methods are used for the assessment of price-risk. The data of Market Clearing Price (MCP) available at Indian Energy Exchange (IEX) are used for the calculation of risk. The results are discussed in detail.

## Keywords

Electricity Market, Risk, Power Exchange.

## 1. INTRODUCTION

All over the world, energy markets have been, or are in the process of being restructured. Due to deregulation in power market, new uncertainties are introduced. Risk is defined as the possibility of loss, injury, disadvantage or destruction [1]. Risk is the hazard to which a market participant is exposed because of uncertainty [1]. Today, every utility is exposed to risk due to market price fluctuations (market price risk), which can have a deep impact on the income statement and balance sheet. To begin with, companies used to focus on market price risk but they soon realized other risks must be considered, including:

- Liquidity risk, which could be divided in volume and margin risk
- Credit risk, particularly worrying in OTC (over the contour) markets
- Regulatory risk
- Operational risk

The risk management issue from power systems points of view is given in [3].

This paper mainly focuses on risk due to price-volatility. The Day Ahead Market with reference to Indian Electricity Market is studied and using the data of market clearing prices (MCP) & market clearing volume (MCV) available on Indian Energy Exchange (IEX) and Power Exchange India Limited (PXIL), the risk is evaluated at each hour using Value at Risk (VaR) & Conditional Value at Risk (CVaR) method. The VaR and CVaR methods are discussed in detail in the paper. Also the algorithm of applying these methods for calculation of risk is reported along with cases and results.

## 2. RISK MANAGEMENT

A simple way to define risk management is: The process of identifying, evaluating, and mitigating the risks that threaten the strategic and financial goals of your business. Also we can define Risk management is the process of achieving the desired balance of risk and return through a particular trading strategy [1]. In the financial literature, risk management at least includes two aspects: risk control and risk assessment as shown in Fig. 1.

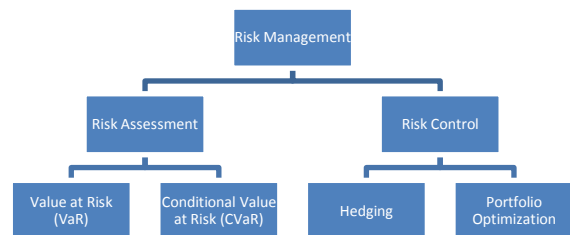


Fig. 1: Risk Management

This is why most utilities work actively on financial risk management. Although there are many strategies, such as hedging, arbitrage or speculation, most companies know what they want their 'core business' to be, so they just try to swap their risks in order to control and limit risk exposures. To achieve this, a wide variety of physical and financial contracts are currently traded in the utility markets.

There are so many risk factors which can affect the profit of an electricity producer; examples are: varying electricity and fuel prices, varying demand, equipment malfunctions and defaulted payments.

Power trading is an integral aspect of competitive power markets. By efficiently managing risk, energy trading helps to ensure reliable electricity at stable prices, and promotes transparent energy markets. Therefore, risk management tools have become more and more important in electricity generation, planning and market operations. In other words, proper risk management tool is essential for energy companies to maximize profits and survive in the market with high volatility.

### 3. RISK ASSESSMENT & CONTROL

For risk assessment, Value at Risk (VaR) is an effective way of measuring the risk and has been applied in electricity market [2].

#### 3.1 Value at Risk (VaR)

The Global Derivatives Study Group, a former promoter of VaR, defines VaR as “the expected loss for an adverse market movement with a specified probability over a particular period of time”[2]. Essentially, VaR is a monetary value that the portfolio will lose less than that amount over a specified period of time with a specified probability.

VaR summarizes the expected maximum loss over a target horizon within a given confidence interval. VaR does not provide a measure of the potential losses exceeding the VaR value;

- Choosing a portfolio to optimize VaR may cause a stretch in the loss distribution tail which creates potential for even larger losses that exceed VaR;
- VaR is difficult to optimize except when assuming normal distributions for underlying market variables.

A method called Conditional VaR has been preferred in recent years to overcome the listed limitations of VaR.

#### 3.2 Conditional Value-at-Risk

Conditional Value-at-Risk (VaR) is also known as the mean excess loss [2]. CVaR overcomes at least one of VaR’s limitations: measuring the potential losses exceeding VaR. By calculating the mean of the loss exceeding the VaR value, CVaR provides a better indication of the potential losses exceeding the assumed confidence level.

CVaR is defined as the conditional expectation of losses given that the loss exceeds a threshold value (VaR value).

Assessment of risk is done using historical method for a given quantity of electricity purchased from power exchange [2]. Value at risk (Var) and Conditional Value at risk (CVar) for a confidence interval of 95% and 99% are calculated, which gives risk associated with given quantity of power purchase.

#### 3.3 Risk Control – Hedging

Definition of Hedge

- Using the futures or options markets to manage price risks
- A temporary substitution of a futures market transaction for a planned cash market transaction
- Taking equal and opposite positions on the cash and futures markets

Hedging is buying of a derivative to offset the risk of a cash position, which is the amount of energy owned. Derivatives are financial instruments (contracts) that do not represent ownership rights in energy but, rather, derive their value from

the value of some other underlying commodity or other asset. When used prudently, derivatives are efficient and effective tools for isolating financial risk and “hedging” to reduce exposure to risk. The most commonly used derivative contracts include Forward Contracts, Futures Contracts, Options and Swaps etc. [2].

### 4. POWER EXCHANGE

Power exchange is a market place where Electricity is traded. It provides a platform to market participant where they can sell or buy electricity, where prices are decided by market itself. A power exchange contributes significantly to facilitating trade and distribution of market information, promoting competition and creation of liquidity in a deregulated power market. The day-ahead spot market provides a neutral, transparent reference price for both the wholesale and retail markets. Further,

- It provides a reference price for bilateral power trade.
- It serves as a reliable counterparty.
- It provides easy access to a physical market at low transaction costs.
- It serves as a grid congestion management tool.
- It creates the possibility of balancing portfolios close to operation.
- It distributes relevant neutral market information and
- It is a non-mandatory power exchange, as an alternative to bilateral contract trade.

Exchange operations so far **Indian Energy Exchange (IEX), Delhi** was the first exchange in the country to start operations, June 27, 2008. **Power Exchange India Limited (PXIL), Mumbai**, started operations on October 22, 2008. Both exchanges have been operating successfully. Following are the features of Indian Exchanges.

- Nation-wide, electronic exchange for trading of Power
- Exchange will handle power trading and transmission clearance simultaneously
- Transparent, neutral and efficient electronic platform
- Trading to start with day-ahead contracts (all 24 hours)
- No separate booking of Transmission Corridor required
- All the participants come to one single platform and get access to each other on a national basis
- Buyers and sellers can participate directly
- Exchange to guarantee payments to sellers
- Buyers - All confirmed trades on the exchange to be scheduled and deviations to be settled through unscheduled interchange (UI)
- Online Buying/Selling of Power

## 5. CALCULATION OF RISK

### 5.1 VaR Calculation of Actual Data using Historical Method

Value at risk (VaR) & Conditional value at risk (CVaR) methods are used at 95% confidence level & 99% confidence level. Two cases are studied:

- Case – I: 10 MW power is purchased from market for whole day.
- Case – II: 285 MW power is purchased from market for whole day.

(Actually hourly MW power purchased from market will not be constant but for the sake of simplicity, the constant power transaction is assumed as 10 MW & 285 MW).

Algorithm for Value at Risk (Var) calculation for one hour is given in next paragraph.

#### Algorithm

1. Compose an array of prices representing the payment made by utility company for purchase of power for each of the 100 days each hour.
2. Calculate an array of the changes in amount of payment made by utility from the previous day's payment.
3. Order this difference values from largest positive to largest negative.
4. To compute the 99% confidence level VaR, using the historical data, a value is chosen which is greater than 99% of all losses experienced in the historical sample period.
5. The definition of 99% confidence level VaR is 'the VaR (the value) such that a given loss will exceed this value only 1% of the time'. So, the second ordered value is selected as the VaR at 99% confidence level.
6. The definition of 95% confidence level VaR is the VaR (the value) such that a given loss will exceed this value only 5% of the time. So, the sixth ordered value is selected as the VaR at 95% confidence level.

#### Case – I: 10 MW power is purchased from market for whole day.

Following above algorithm value at risk is calculated for 95% and 99% confidence level. Table 1 shows the risk at 95% confidence level and at 99% confidence level for 10 MW purchase of power from Power Exchange for 1st April 2010 for 24 hours of day.

In Table 1, Column 1 represents 24 hours for whole day. Column 2 shows the MW power purchased from power exchange for every hour. Column 3 shows the hourly spot price (collected from Indian Energy Exchange) on 1st April 2010. Column 4 shows the calculated expected cost in Rs. for purchasing 10 MW for whole day.

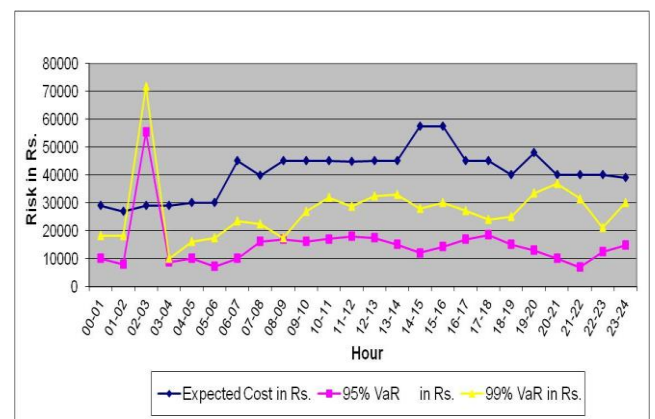
$$\text{Expected Cost} = \text{Hourly Spot Price} \times 10 \quad \text{----- (1)}$$

Column 5 represents the hourly magnitude of risk at 95% confidence level. Column 6 gives the percentage magnitude of risk with reference to expected cost at 95% confidence level.

Column 7 and column 8 represents the hourly magnitude of risk and the percentage magnitude of risk with reference to expected cost at 99% confidence level respectively.

**Table 1**  
**VaR for 10 MW Purchase from Exchange for 1st April 2010.**

VaR for 10 MW Purchase from Exchange for 1st April 2010							
Hour	Volume Purchased from Power Ex. (MW)	Spot Price on 1st April 2010 (Rs.)	Expected Cost Spot price *10 (Rs.)	VaR at 95% Confidence Level (Rs.)	Percentage VaR at 95% Confidence Level (Rs.)	VaR at 99% Confidence level (Rs.)	Percentage VaR at 99% Confidence Level
00-01	10.00	2901.68	29016.80	10019.10	34.53	15014.00	51.74
01-02	10.00	2700.95	27009.50	7835.50	29.01	18007.30	66.67
02-03	10.00	2906.01	29060.10	55200.96	189.95	71328.02	245.45
03-04	10.00	2907.68	29076.80	8714.00	29.97	10009.10	34.42
04-05	10.00	2996.57	29965.70	9995.90	33.36	15022.10	50.13
05-06	10.00	3000.72	30007.20	7023.30	23.41	15508.50	51.68
06-07	10.00	4498.86	44988.60	10002.50	22.23	19329.40	42.97
07-08	10.00	3991.49	39914.90	16013.70	40.12	21428.00	53.68
08-09	10.00	4499.46	44994.60	17001.70	37.79	17502.10	38.90
09-10	10.00	4499.64	44996.40	16016.40	35.59	25023.50	55.61
10-11	10.00	4499.63	44996.30	17016.40	37.82	27002.70	60.01
11-12	10.00	4489.91	44899.10	18017.00	40.13	27005.40	60.15
12-13	10.00	4499.22	44992.20	17503.50	38.90	27009.50	60.03
13-14	10.00	4499.91	44999.10	15030.70	33.40	25020.90	55.60
14-15	10.00	5739.44	57394.40	12013.20	20.93	25583.60	44.58
15-16	10.00	5739.37	57393.70	14230.60	24.79	27018.50	47.08
16-17	10.00	4499.31	44993.10	17000.80	37.79	26560.40	59.03
17-18	10.00	4499.19	44991.90	18498.40	41.11	22638.50	50.32
18-19	10.00	3999.58	39995.80	15014.00	37.54	22495.60	56.24
19-20	10.00	4800.76	48007.60	12898.30	26.87	32005.50	66.67
20-21	10.00	3999.74	39997.40	10005.60	25.02	25006.70	62.52
21-22	10.00	3999.69	39996.90	6988.40	17.47	20016.60	50.05
22-23	10.00	3999.54	39995.40	12499.40	31.25	20013.30	50.04
23-24	10.00	3892.89	38928.90	14735.50	37.85	25992.40	66.77
Average Value			40858.85	14969.79	38.62	24230.90	61.68



**Fig. 2: VaR for 10 MW Purchase from Exchange for 1st April 2010**

It can be observed from Table 1 & Fig. 2 that minimum spot price and maximum spot price for trading day (1st April 2010) are Rs. 2700.95 and Rs. 5739.44 respectively. The minimum value of Value at Risk at 95% and 99% confidence level are observed as Rs. 6988.0 and Rs. 10104.0 respectively. The maximum value of Value at Risk at 95% and 99% confidence level are observed as Rs. 55200.0 and Rs. 71593.0 respectively. Daily average percentage VaR at 95% confidence level are 38.6% and at 99% confidence level is 61.6%. If utility company blindly goes for trading, company is imposing to a huge amount of risk.

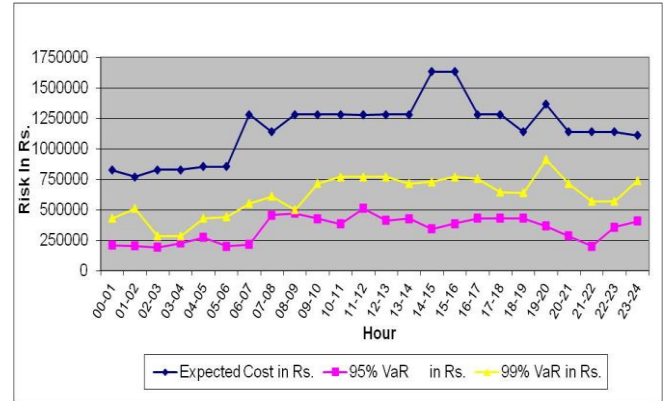
**Case – II: 285 MW power is purchased from market for whole day.**

Following the same algorithm, the magnitude of risk is calculated for purchase of 285 MW power from power exchange on 1st April 2010 for whole day. Table 2 shows the result.

It can be observe from Table 2 & Fig. 3 that minimum spot price and maximum spot price for trading day (1st April 2010) are Rs. 2700.95 and Rs. 5739.44 respectively. The minimum value of Value at Risk at 95% and 99% confidence level are observed as Rs. 191947.50 and Rs. 427899.0 respectively.

**Table 2**  
**VaR for 285 MW Purchase from Exchange for 1st April 2010.**

VaR for 285 MW Purchase from the Exchange for 1st April 2010							
Hour	Volume Purchased from Power Ex. (MW)	Spot Price on 1st April 2010 (Rs.)	Expected Cost = Spot Price * 285 (Rs.)	VaR at 95% Confidence Level (Rs.)	Percentage VaR at 95% Confidence Level (Rs.)	VaR at 99% Confidence level (Rs.)	Percentage VaR at 99% Confidence Level
00-01	285	2901.68	826978.80	208990.50	25.27	427899.00	51.74
01-02	285	2700.95	769770.75	203746.50	26.47	513208.05	66.67
02-03	285	2906.01	828212.85	191947.50	23.18	285059.85	34.42
03-04	285	2907.68	828688.80	227905.95	27.50	285259.35	34.42
04-05	285	2996.57	854022.45	271054.95	31.74	428129.85	50.13
05-06	285	3000.72	855205.20	200164.05	23.41	441992.25	51.68
06-07	285	4498.86	1282175.10	213895.35	16.68	550887.90	42.97
07-08	285	3991.49	1137574.65	455452.80	40.04	610698.00	53.68
08-09	285	4499.46	1282346.10	470369.70	36.68	498809.85	38.90
09-10	285	4499.64	1282397.40	427420.20	33.33	713169.75	55.61
10-11	285	4499.63	1282394.55	384613.20	29.99	769576.95	60.01
11-12	285	4489.91	1279624.35	513285.00	40.11	769653.90	60.15
12-13	285	4499.22	1282277.70	410174.85	31.99	769770.75	60.03
13-14	285	4499.91	1282474.35	426710.55	33.27	713095.65	55.60
14-15	285	5739.44	1635740.40	341532.60	20.88	729132.60	44.58
15-16	285	5739.37	1635720.45	385311.45	23.56	770027.25	47.08
16-17	285	4499.31	1282303.35	427616.85	33.35	756971.40	59.03
17-18	285	4499.19	1282269.15	427719.45	33.36	645197.25	50.32
18-19	285	3999.58	1139880.30	427899.00	37.54	641124.60	56.24
19-20	285	4800.76	1368216.60	367601.55	26.87	912156.75	66.67
20-21	285	3999.74	1139925.90	285159.60	25.02	712690.95	62.52
21-22	285	3999.69	1139911.65	199169.40	17.47	570473.10	50.05
22-23	285	3999.54	1139868.90	356232.90	31.25	570379.05	50.04
23-24	285	3892.89	1109473.65	407381.85	36.72	740783.40	66.77
Average Value			1164477.23	342973.16	29.40	617756.14	52.89



**Fig. 3: Var for 285 MW Purchase from Exchange for 1st April 2010**

The maximum value of Value at Risk at 95% and 99% confidence level are observed as Rs. 513285.0 and Rs. 912156.75 respectively. Daily average percentage VaR at 95% confidence level are 29.40% and at 99% confidence level is 52.88%. If utility company blindly goes for trading, company is imposing to a huge amount of risk.

Calculated VaR does not provide a measure of the potential losses exceeding the VaR value. Also, it may cause a stretch in the loss distribution tail which creates potential for even larger losses that exceed VaR value. CVar method gives more accurate result and overcome limitations of VaR.

**5.2 Calculation of Risk using Conditional Value at Risk**

The average of the six largest ordered loss values evaluated following the algorithm of VaR gives the CVaR at 95% confidence level.

As per definition of CVaR, the CVaR at 99% confidence level is simply the average of the two largest ordered loss values (i.e. first two ordered value).

Same two cases are studied and CVaR is evaluated for both cases at two confidence level.

**Case – I: 10 MW power is purchased from market for whole day.**

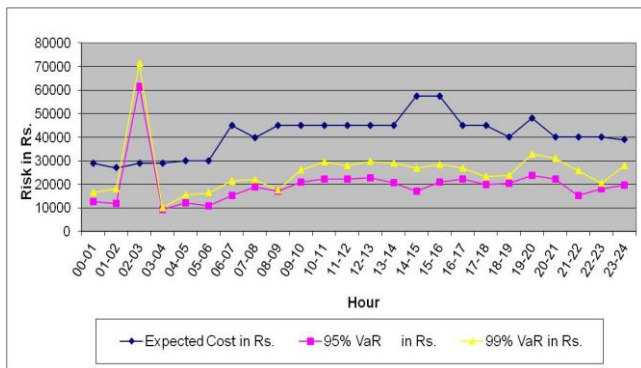
Following same algorithm of value at risk, conditional value at risk is calculated for 95% and 99% confidence level. Table 3 & Fig. 4 shows the risk at 95% confidence level and at 99% confidence level for 10 MW purchase of power from Power Exchange for 1st April 2010 for 24 hours of day.

In Table 3, Column 1 represents 24 hours for whole day. Column 2 shows the MW power purchased from power exchange for every hour. Column 3 shows the hourly spot price (collected from Indian Energy Exchange) on 1st April 2010. Column 4 shows the calculated expected cost in Rs. for purchasing 10 MW for whole day. Expected Cost is given by equation 1.

Column 5 represents the hourly magnitude of CVaR at 95% confidence level. Column 6 gives the percentage magnitude of risk (CVaR) with reference to expected cost at 95% confidence level. Column 7 and column 8 represents the hourly magnitude of CVaR and the percentage magnitude of CVaR with reference to expected cost at 99% confidence level respectively.

**Table 3**  
**CVaR for 10 MW Purchase from Exchange for 1st April 2010.**

CVaR for 10 MW Purchase from the Exchange for 1st April 2010							
Hour	Volume Purchased from Power Ex. (MW)	Spot Price on 1st April 2010 (Rs.)	Expected Cost = Spot price *10 (Rs.)	CVaR at 95% Confidence Level (Rs.)	Percentage CVaR at 95% Confidence Level (Rs.)	CVaR at 99% Confidence level (Rs.)	Percentage CVaR at 99% Confidence Level
00-01	10	2901.68	29016.80	12744.55	43.92	16599.65	57.21
01-02	10	2700.95	27009.50	11861.45	43.92	18098.70	67.01
02-03	10	2906.01	29060.10	61618.68	212.04	71460.86	245.91
03-04	10	2907.68	29076.80	9304.12	32.00	10057.00	34.59
04-05	10	2996.57	29965.70	12177.65	40.64	15502.70	51.73
05-06	10	3000.72	30007.20	10778.40	35.92	16398.30	54.65
06-07	10	4498.86	44988.60	15268.02	33.94	21389.05	47.54
07-08	10	3991.49	39914.90	18819.47	47.15	21959.30	55.02
08-09	10	4499.46	44994.60	17170.50	38.16	17504.15	38.90
09-10	10	4499.64	44996.40	20924.82	46.50	26013.95	57.81
10-11	10	4499.63	44996.30	22244.28	49.44	29468.85	65.49
11-12	10	4489.91	44899.10	22338.60	49.75	27903.70	62.15
12-13	10	4499.22	44992.20	22629.50	50.30	29689.15	65.99
13-14	10	4499.91	44999.10	20772.68	46.16	29011.80	64.47
14-15	10	5739.44	57394.40	17037.23	29.68	26797.55	46.69
15-16	10	5739.37	57393.70	20973.98	36.54	28537.45	49.72
16-17	10	4499.31	44993.10	22163.48	49.26	26796.55	59.56
17-18	10	4499.19	44991.90	19914.88	44.26	23347.10	51.89
18-19	10	3999.58	39995.80	20307.83	50.77	23801.00	59.51
19-20	10	4800.76	48007.60	23753.30	49.48	32757.25	68.23
20-21	10	3999.74	39997.40	22335.65	55.84	30999.80	77.50
21-22	10	3999.69	39996.90	15248.95	38.13	25755.45	64.39
22-23	10	3999.54	39995.40	18169.05	45.43	20515.35	51.29
23-24	10	3892.89	38928.90	19675.57	50.54	28002.30	71.93
Average Value			40858.85	19926.36	50.82	25765.29	65.38



**Fig. 4: CVaR for 10 MW Purchase from Exchange for 1<sup>st</sup> April 2010.**

**Case – II: 285 MW power is purchased from market for whole day.**

Following the same steps of calculation of 10 MW CVaR, evaluation of CVaR of 285 MW power on 1st April for same two confidence level is done. Table 4 shows the result. From Table 4 and Fig. 5, the minimum value of Conditional Value at Risk at 95% and 99% confidence level are observed as Rs.259567.55 and Rs. 286624.50 respectively. The maximum value of Conditional Value at Risk at 95% and 99% confidence level are observed as Rs. 676969.05 and Rs. 933581.63 respectively. Daily average percentage CVaR at 95% confidence level are 43.29% and at 99% confidence level is 56.93%. Utility company may remove risk by adopting proper risk management strategies.

**Table 4**  
**CVaR for 285 MW Purchase from Exchange for 1st April 2010.**

CVaR for 285 MW Purchase from the Exchange for 1st April 2010							
Hour	Volume Purchased from Power Ex. (MW)	Spot Price on 1st April 2010 (Rs.)	Expected Cost = Spot Price *285 (Rs.)	CVaR at 95% Confidence Level (Rs.)	Percentage CVaR at 95% Confidence Level (Rs.)	CVaR at 99% Confidence level (Rs.)	Percentage CVaR at 99% Confidence Level
00-01	285	2901.68	826978.80	363219.68	43.92	473090.03	57.21
01-02	285	2700.95	769770.75	338051.33	43.92	515812.95	67.01
02-03	285	2906.01	828212.85	259567.55	31.34	356452.35	43.04
03-04	285	2907.68	828688.80	265167.33	32.00	286624.50	34.59
04-05	285	2996.57	854022.45	347063.03	40.64	441826.95	51.73
05-06	285	3000.72	855205.20	307184.40	35.92	467351.55	54.65
06-07	285	4498.86	1282175.10	435138.48	33.94	609587.93	47.54
07-08	285	3991.49	1137574.65	536354.80	47.15	625840.05	55.02
08-09	285	4499.46	1282346.10	489359.25	38.16	498868.28	38.90
09-10	285	4499.64	1282397.40	596357.28	46.50	741397.58	57.81
10-11	285	4499.63	1282394.55	633962.08	49.44	839862.23	65.49
11-12	285	4489.91	1279624.35	636650.10	49.75	795255.45	62.15
12-13	285	4499.22	1282277.70	644940.75	50.30	846140.78	65.99
13-14	285	4499.91	1282474.35	592021.48	46.16	826836.30	64.47
14-15	285	5739.44	1635740.40	485561.15	29.68	763730.18	46.69
15-16	285	5739.37	1635720.45	597758.53	36.54	813317.33	49.72
16-17	285	4499.31	1282303.35	631659.28	49.26	763701.68	59.56
17-18	285	4499.19	1282269.15	567574.18	44.26	665392.35	51.89
18-19	285	3999.58	1139880.30	578773.25	50.77	678328.50	59.51
19-20	285	4800.76	1368216.60	676969.05	49.48	933581.63	68.23
20-21	285	3999.74	1139925.90	636566.03	55.84	883494.30	77.50
21-22	285	3999.69	1139911.65	434595.08	38.13	734030.33	64.39
22-23	285	3999.54	1139868.90	517817.93	45.43	584687.48	51.29
23-24	285	3892.89	1109473.65	560753.65	50.54	798065.55	71.93
Average Value			1164477.23	505544.40	43.29	664303.18	56.93

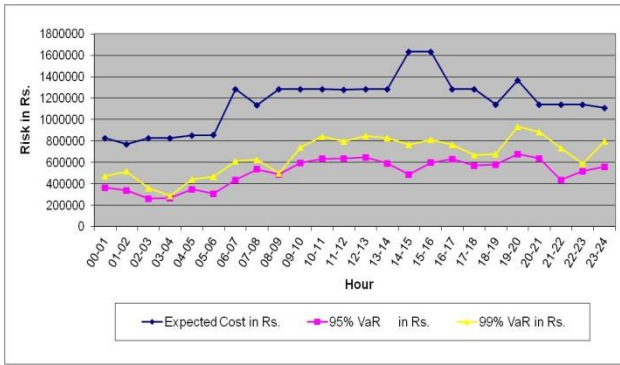


Fig. 5: CVaR for 10 MW Purchase from Exchange for 1<sup>st</sup> April 2010.

## 6. CONCLUSION

Power trading is an integral aspect of competitive power markets. By efficiently managing risk, energy trading helps to ensure reliable electricity at stable prices, and promotes transparent energy markets.

In this paper risk due to price volatility is discussed with reference to Indian Electricity Market. Using the data of market clearing prices (MCP) & market clearing volume (MCV) available on Indian Energy Exchange (IEX) and Power Exchange India Limited (PXIL), the risk is evaluated at each hour using Value at Risk (VaR) & Conditional Value at Risk (CVaR) method. The assessment of risk is important task of risk management. The VaR & CVaR method gives monetary value of risk enabling utilities to hedge risk.

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