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ON

Short Term Power Procurement for The State of Rajasthan

Submitted in partial fulfillment of the

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In

Renewable Energy

By

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JAIPUR, RAJASTHAN (302017)

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This is certified that the dissertation report entitled **"Short Term Power Procurement for The State of Rajasthan"** prepared by **KRISHAN GOPAL SHARMA** (ID-2018PCV5042), in the partial fulfillment of the award of the Degree, **Master of Technology** in **Renewable Energy** of Malaviya National Institute of Technology Jaipur is a record of bonafidedissertationcarried out by him under my supervision and is hereby approved for submission. The contents of this dissertation work, in full or in parts, have not been submitted to any other Institute or University for the award of any degree or diploma.

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Declaration

I,**Krishan Gopal Sharma** hereby declare that the dissertation report entitled **“Short Term Power Procurement for The State of Rajasthan”**being submitted by me in partial fulfillment of the degree of **M. Tech (Renewable Energy)** is a research work carried out by me under the supervision of**Dr.RohitBhakar and Dr.ParulMathuria** and the contents of this work, in full or in parts, have not been submitted to any other Institute or University for the award of any degree or diploma. I also certify that no part of this dissertation work has been copied or borrowed from anyone else. In case any plagiarism is found out, I will be solely and completely responsible for it.

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Krishan Gopal Sharma

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Abstract

The swinging regard to competition in the energy sector has led an endeavor to find out an appropriate volume of power to be procured through long-term power purchase agreements (PPAs), the volume to be sourced fromshort-term power exchange i.e. day-ahead and term-ahead and self-generation, which would finally lead to the optimum cost of power procurement.The power sector in Rajasthan has shown a substantial improvement over the past few years or in a decade due to increase in generation capacity, renewable generation, strengthening of network infrastructure leading to an improvement in the overall power supply position of the state.

This study has considered a Rajasthan-based power distribution utility and has collected all relevant data from its archival sources. A linear optimization model has been developed to capture the problem of power procurement faced by the distribution utility, which is modelled as a linear programming problem (GAMS). Sensitivity analyses were carried out on the important parameters including hourly demand of power, unit variable cost of power available through PPA, etc., to investigate their impact on daily cost of power under PPAs, daily cost of power under day- ahead and term-ahead options, and also then total daily cost of power procurement.

The findings include the relevant volume of power acquire from different suppliers through PPAs, power exchange under day-ahead and term-ahead options and the surplus volume of power sold under the day-ahead arrangement. It could lead us to the better energy market operation and could help in achieving economies of scale. In addition, it has also presented the results of sensitivity analyses, which provider in managerial understanding.

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List of Abbreviations

PPA	Power purchase agreement
SLDC	State load dispatch centre
MU	Million unit
STM	Short term market
TAM	Term ahead market
DAM	Day ahead market
DSM	Deviation settlement mechanism
AS	Ancillary services mechanism
PX	Power exchange
CERC	Central electricity regulatory commission
POSOCO	Power system operation coroporation limited
CAGR	Compound annual growth rate
RES	Renewable energy supply
EA	Electricity act
STU	State transmission utility
ISGS	Inter-state generating stations
SERC	State electricity regulatory commission
OA	Open acces

LDC	Load distribution company
IPP	Independent power purchase
GAMS	General algebraic modeling system
MW	Mega watt.
RPO	Renewable power purchase obligation
GOI	Government of India.
IEX	Indian energy exchange
FY	Financial year
DISCOM	Distribution company
CSS	Cross subsidy surcharge

Chapter-1 Introduction

Rajasthan is the largest state in the geographical area in the country. The power sector in Rajasthan has witnessed substantial improvement over the past decade due to an increase in generation capacity and strengthening of network infrastructure leading to an improvement in the overall power supply position of the state [1]. Currently, the demand and supply have been improved to such an extent that can be well enumerated as follows:

- Continuous 24X7 supply to the residential consumers and making commercial connections lucrative and attractive through easy schemes.
- Nearly all unconnected households have proper access to electricity by now.
- To ensure adequate capacity addition planning & tie-ups for power from various sources at an affordable price to meet the projected increase in power demand for the future [3].
- Measures such as energy mix optimization, reduction in power procurement costs, improving operational efficiency of state generation plant, and optimal fuel procurement costs including sources of supply.

So to reduce the overall cost of procurement. The enactment of the electricity act 2003 leads to the introduction of non-discriminatory open access and further added a value-based motivation for enhancing competition in the electricity market.

This cumulative effort has been supported by the positive regulatory moves to create a vibrant electricity market supported by the efforts of market operators and market makers in bringing out new and efficient purchase, sell, and biding for the consumers, suppliers, and the sector as a whole [1].

The structure of the new market, which has taken definite shape in the last few years, has helped various utilities, Ipps, and distribution utilities in every prospect like generation, transmission reliability and satisfying end consumer need in dynamic format. With such well-defined paths and the time-bound structured market to optimize their power purchase portfolios and reduce their overall power purchase costs efficiently [2].

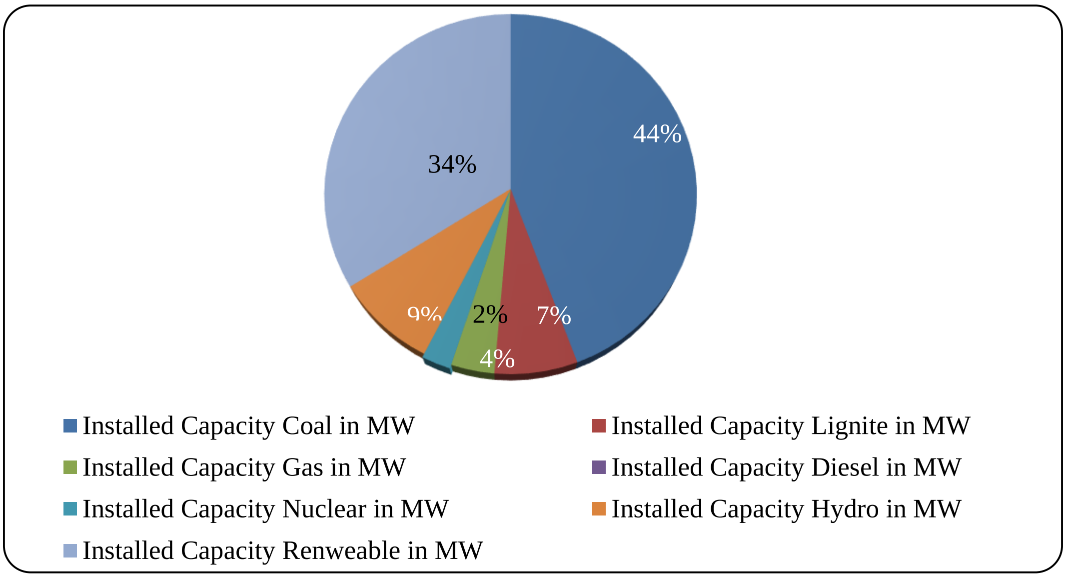


Figure 1-1 Installed Capacity Generation Mix Type

1.1 Rajasthan Power Supply Position

It has become imperative to study the power status of Rajasthan as this would help us to find the better option of generation look out and how generations and the other available resource can be enhanced to meet the future demand and further the sudden hike in demand can be bridged up with what best possible options.

1. From fig 1.1 thermal energy (mainly from Coal) is an important source of electricity generation in Rajasthan, contributing about 44% of the total installed generation capacity in 2019,followed by Renewable Energy Source (RES) (34.0%), Hydro (9.0%), and Nuclear (2.0%), Gas (4%), Lignite based power plant (7%).

2. The Compound annual growth rate (CAGR) of entirety installed generation capacity was 3% during the phase starting 2018-19 .major contribution for the increase is due to the new addition of state generation unit and more private renewable generator as Rajasthan geographical condition is best suitable for renewable generation.

3. The private sector continues to be the major holder, holding 51% share in 2019 as it can be noted through figure 1.2.the incentive and the aiding scheme promotes more new renewable generator to come forward for quality and quantitative

generation.

1.2 Sector Wise Installed Capacity

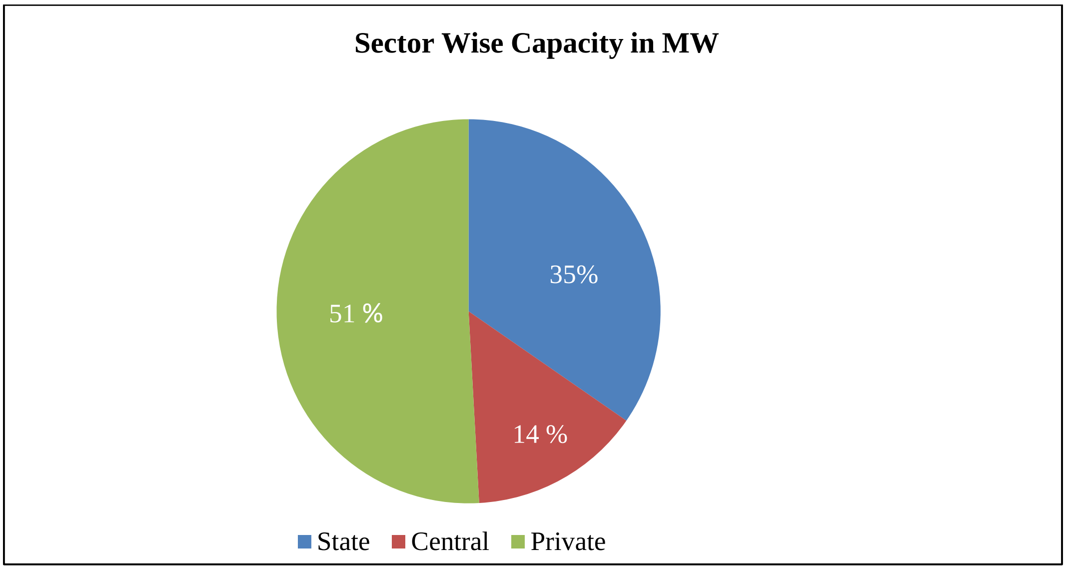


Figure 1-2 Sector Wise Installed Capacity

The ElectricityAct of 2003 liberalized the electricity generation through a license-freerule. As a result, the entrance of private company into the generation segment notably amplified their share in the full amount electricity generation which is quite notable and appreciable [2,3].The players in the electricity generation segment can be divided into three types based on ownership and operations. These are

1. A central public sector undertaking includes National Thermal Power Corporation, National Hydro electric Power Corporation, and similar organizations.
2. State public sector undertakings/State Electricity Boards; and
3. Private sector enterprises include Tata Power Company Ltd, Reliance Power Ltd, Adani Power Ltd., and similar entities.

- From figure 1.2 During the period from 2019, the share of thestate sector in the total installed generation capacity nearly remained the same with a minute increment as compared to 2018, and share of the central sector has been the same as 14% in 2018.

- With this present increment scenario also leads to less import and enhances more export dominantly is been observed that Rajasthan's increased RE generationas abundance of sunlight, wind resources, further the cheaper capital cost has attracted many private players. Which allows the state to rely less on imports from the rest of the Northern region, particularly Punjab, Haryana, and Uttar Pradesh [4].
- As per the posoco analysis, the import has been reduced by 22% annually and the export has been increased by 11% which depict that Rajasthan itself capable to meet it sudden demand or any other demand variation.

1.3 Installed Capacity Month and Sector Wise

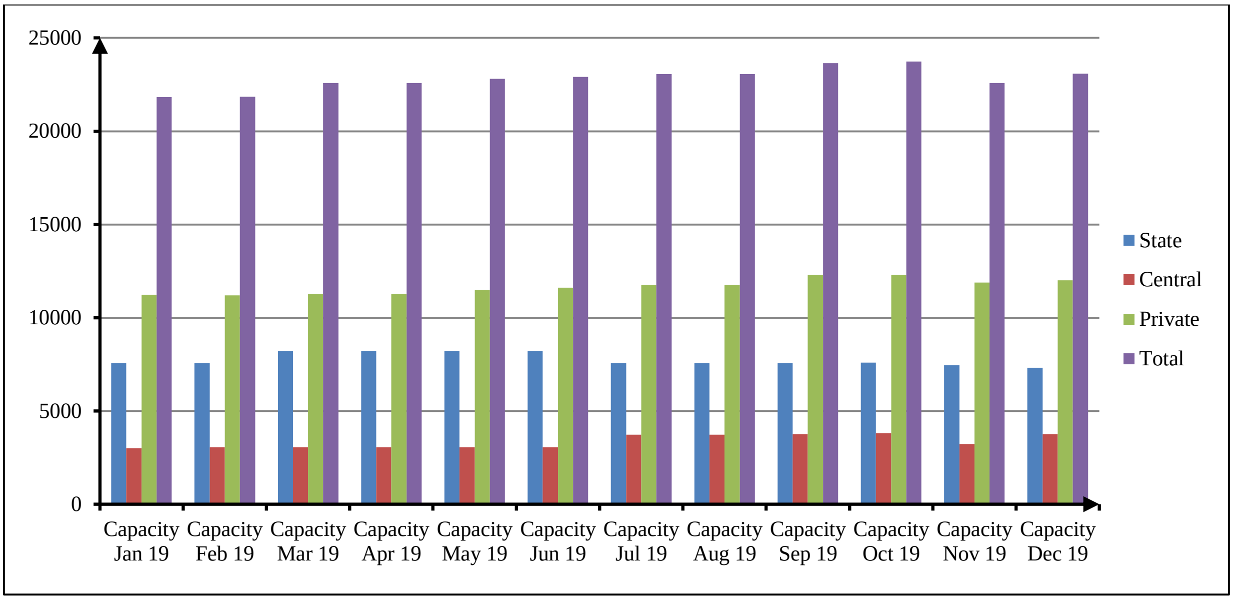


Figure 1-3 Installed Capacity Month Wise

Here in figure 1.3, we conclude that even the private generation is a higher month wise as compared to state and central generation because the generation from the conventional power plant has many challenges like higher technical minimum operation, mismatch in fast ramping of RE & this slow response -imbalance in load-generation [5].

There is a quick boost in the installed electricity generation capacity of RES when compared with all other various power generating sources. If we note in the figure the installed capacity of private generation increases in september and october due to wind generation increase due to high prevailing wind at the time of the year.Whereas the state generation is high during summer to meet the demand as compared to the rest of the months as we know that the cooling demand increases to a greater extent in summer.

1.4 Installed Capacity: State Generation Plant Wise

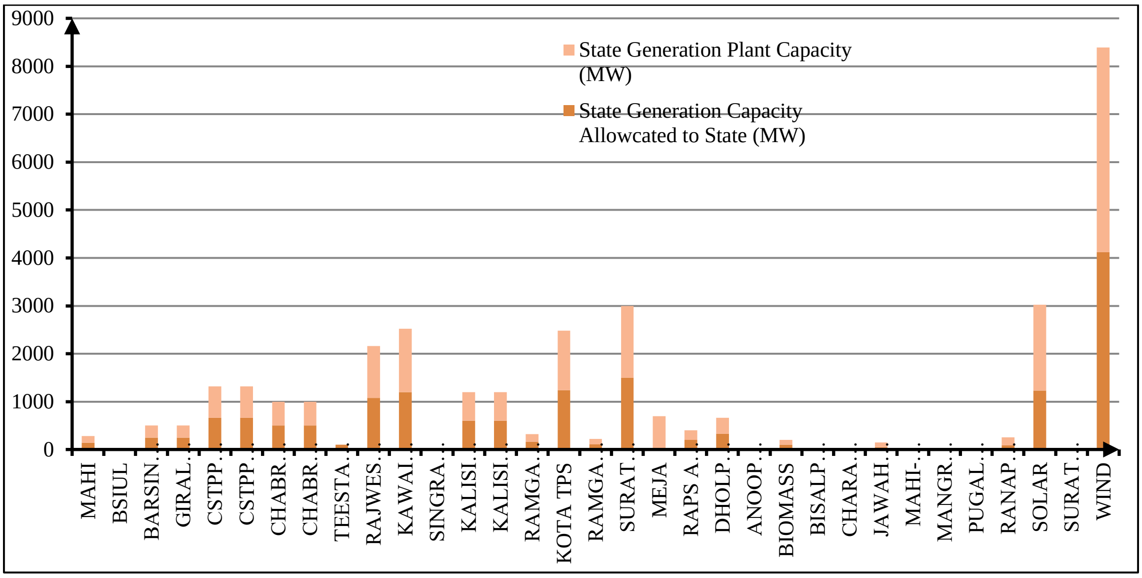


Figure 1-4 Installed Capacity Month Wise of Rajasthan Self Generation

In figure 1.4 we found that there is a great difference between the plant capacity and the generation allocated to the self-generating plant,which leads one to comprehend for the appropriate reason of why the maximum number of the plant is under utilized which may raise many questions in respect to their operating condition, maintenance, outage, etc.

Further, it is found that the maximum number of gas and diesel plant is shutdown due to noavailability of fuel for running and this no operating condition brings the depreciation in the machinery cost along with other increased maintenance cost.

1.5 Installed Capacity:Central ISGS

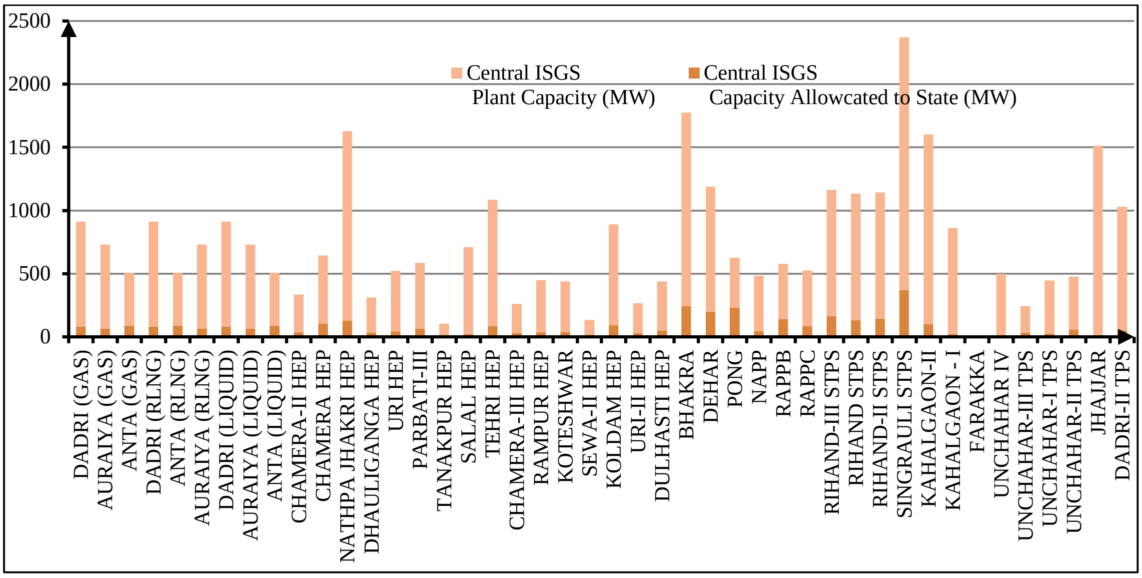


Figure 1-5 Installed Capacity Month Wise from Central ISGS

The plants of central ISGS and its capacity allocated to the state are shown in figure 1.5 and whatever generation is procured through central generator as we are obliged or bound to incur because we have long term PPA or agreement done with them. Further, even if we have low demand and we do not require that quantum of energy but still we have to pay the fixed cost.

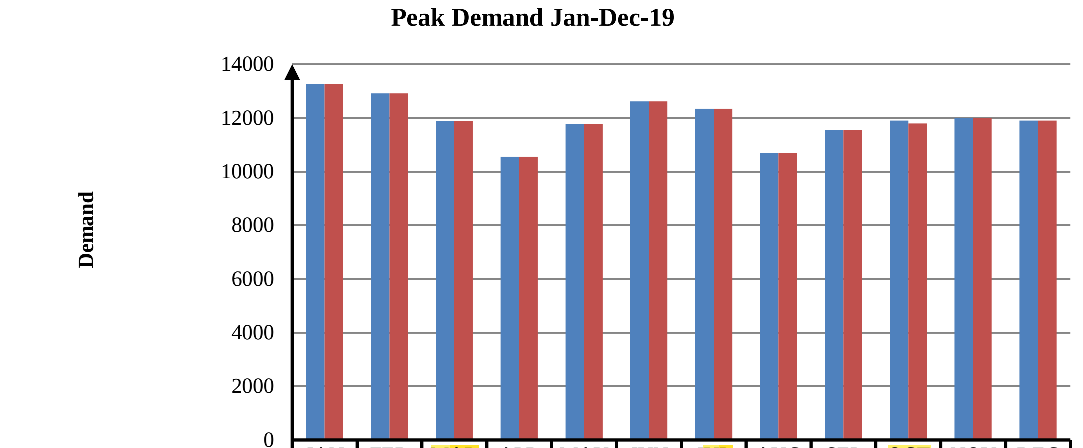
This may show its reflection in the overall cost of procurement to the consumer end. In certain cases, if we want to have a medium-term contract with such a plant for days even then the total procurement cost is higher as compared to the cost when procured through the market.

1.6 Peak Demand

The maximum peak demand in Rajasthan attained so far was 13,276 MW during last year (2019) which was also most fulfilled as per requirement.

This meeting of peak demand per month wise is shown in figure 1.6 where we found that in three months the peak demand is not met and this is a matter of concern because when such situation arises then load shedding is done or gas/ diesel power plant is operated to meet such demand. On the other hand, if this is done so then this gas or diesel power plant has a high variable cost, which can make per unit of electricity unbearable. Therefore, it would be wise to look for some other optimal procurement source, which can provide instant supply against such high seasonal demand at optimal cost and the short-term market can be one of the best options.

Similarly, the demand-supply gap during peak hours in the state has reduced from 7.1% to almost nil in the last five years due to significant addition in generation capacity during the recent past years.



	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Peak Demand in MW 19	13276	12921	11885	10560	11791	12620	12351	10699	11553	11900	12001	11900
Peak Demand Met in MW 19	13276	12921	11880	10560	11791	12620	12348	10699	11553	11800	12001	11900

Figure 1-6 Comparative Graph of Met and Unmet Demand Month wise

1.7 Required and Supplied Energy

In the same way, the energy ease of use in MUs against the requirement of in MUs month wise for the state of Rajasthan is shown in figure 1.7.

The breach between energy prerequisite and energy ease of use in Rajasthan is on the decline since 2011-12 when it was 3.9% and it has now come down to less than 1%. this is one positive prospect for overall development of energy sector of Rajasthan.This deficit reflect that the generation was at par with the demand and satisfactory capacity addition planning & tie ups for power from diverse sources aredone with reasonable prospective to meet the projected increase in seasonal and monthly power demand.

This requirement and supplied balance is to be calculated on monthly basis and is to be noted to CERC so that the exact reason can be notified in each particular scenario if the supply is not fulfilled as par to the requirement.

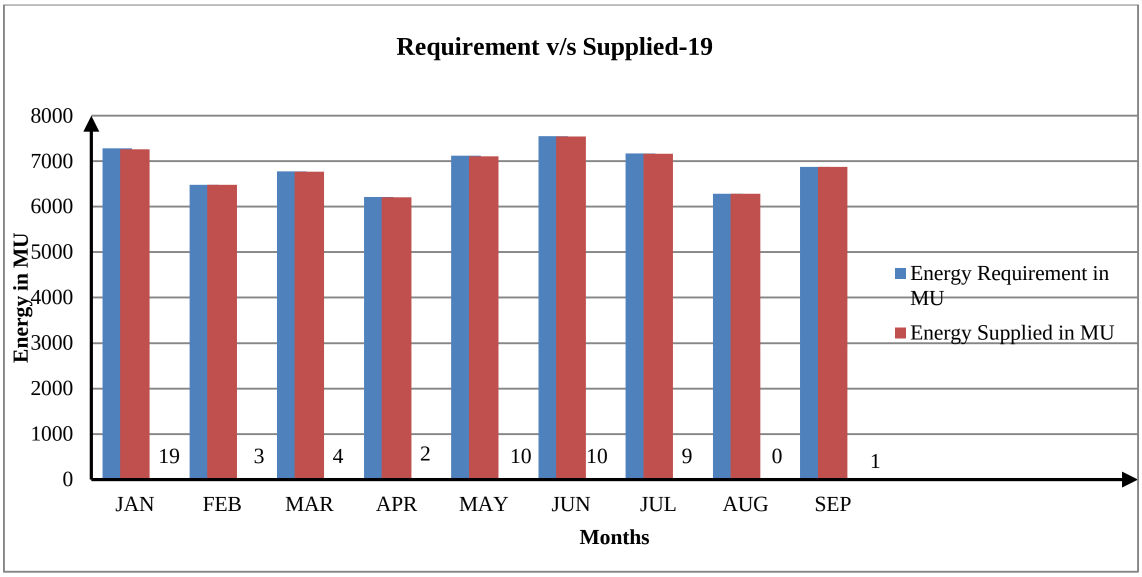


Figure 1-7 Comparative Graph of Required and Supplied Energy Month Wise for Rajasthan

1.8 Generation Comparison Annually

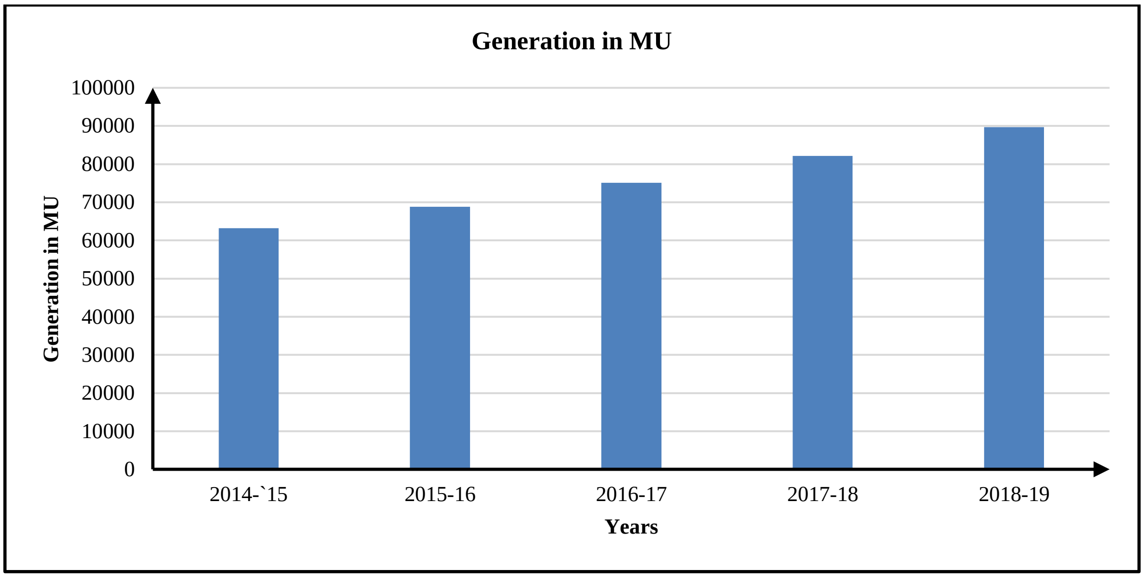


Figure 1-8 Comparative Annual Generation

In the above shown figure 1.8 we seen the annual generation for the state of Rajasthan and it been showing a noticeable increasing trend from the year of 2014. The annual increment from year 2015-15 to 2015-16 was 8.9% , for the year 2015-16 to 2016-17 was 9.1%, for the year 2016-17 to 2017-18 was 9.33% and most recent 2018-18 to 2018-2019 was 9.46%.

From this we can understand the generation and commitment of new plant is been taking place to counter the future demand of the state.The major concern is to fulfill the demand the question may arise if this incremental trend on generation side is at par with the demand. If not then what can be other alternative that can be added to this generation side to fulfill the demand in various time frame during the year.

1.9 Renewable Energy Potential

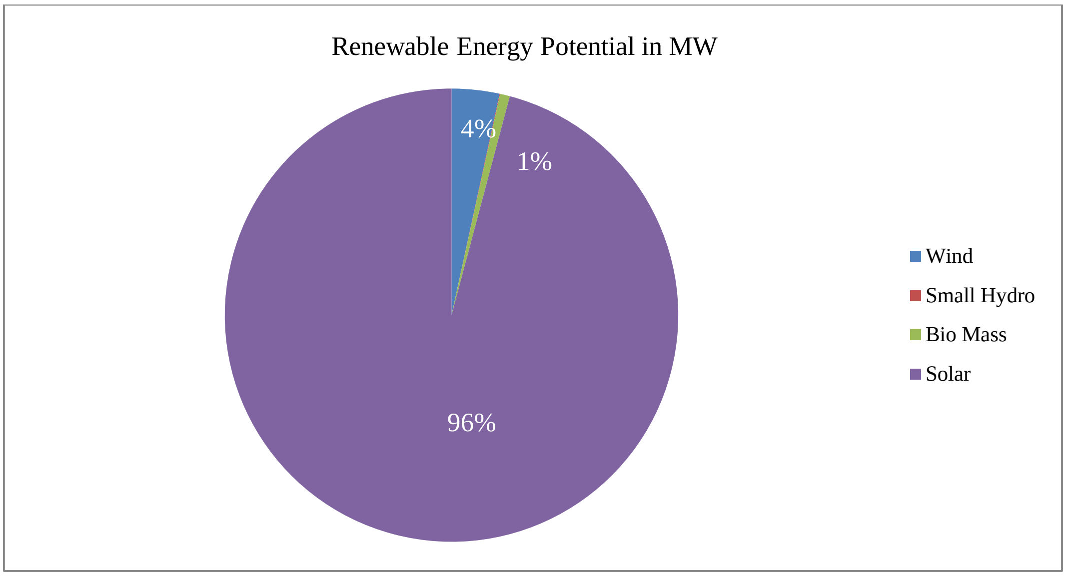


Figure 1-9 Renewable Energy Potential

From the above figure 1.9 we came across the most important fact which was discussed earlier also that the geographical location of Rajasthan has a abundance of sunlight which makes it rich in solar and wind generation.The western part of the state is utilizing such renewable resources with incremental capacity addition every year.

1.10 Annual Average Demand

The demand profile knowledge is vital for a wide variety of power systems studies. Furthermore, meaningful information may be obtained regarding optimization and maximization decision making strategies that may help a wide variety of consumers optimize their facilities usage, redefine low priorities equipment operating hours, as well as promote actions seeking generation increase.

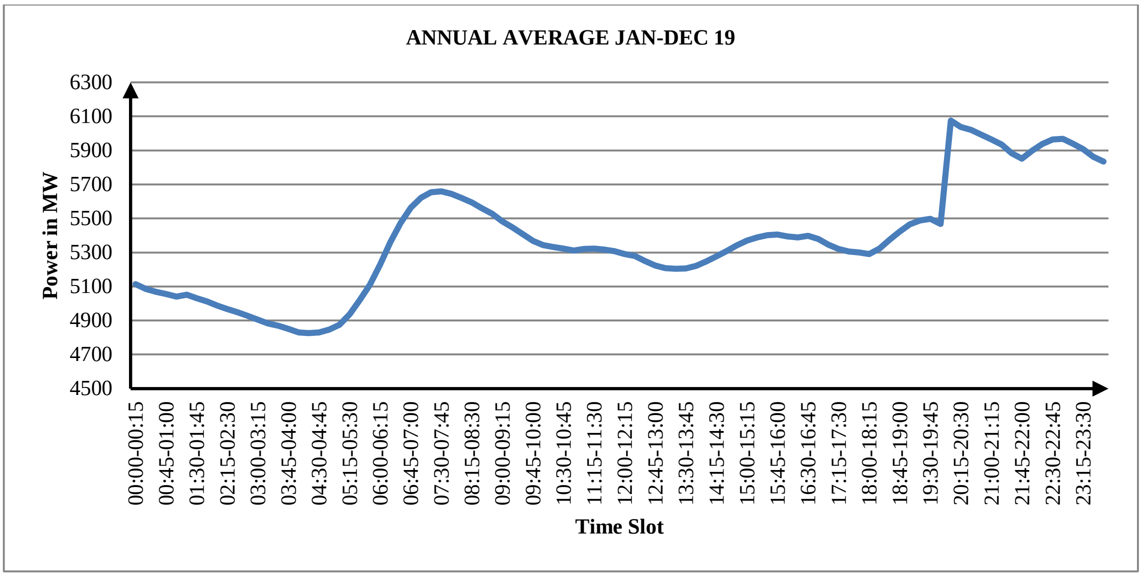


Figure 1-0 Annual Average Demand for the State of Rajasthan 2019

1.11 Organization of thesis

Chapter 1 Describes the basics and the present state of the power supply position for the state of Rajasthan. A brief overview oftheintroduction is discussed in the prospect of procurement scenario in Rajasthan along with sector-wise installed capacity, installed capacity month-wise showing the various changes as per seasonal requirement and generation capacity variation of various sectors. Highlighting the peak demand.

Chapter 2 Presents a summary of the power supply position driven motivation for Rajasthan short term planning. The various important factors are enlisted along with explanation such driving factors are: shortage of power and higher power purchase cost during peak demand, power exchange cheap power utilization and availability, growing renewable penetration increases uncertainties for long term/baseload procurement, fuel shortages (gas and coal),delay in commissioning of power projects, lower level of hydro generation, transmission congestion at different levels. The status of the short-term market in Rajasthan is discussed, with the general prospect of what is short term market and its background, short term power procurement planning structure,the basic principle of planning structure, it's functioning of such structure in the present scenario. For a better understanding of the present status of procurement in Rajasthan, an example based on various procurement cost analysis is done for a single day.

Chapter 3 Brings out the overviews on short term market planning in India. Challenges in short term planning like regulatory challenges, institutional challenges, infrastructural challenges, and operational challenges. Further, the insight can be comprehended for the exact and accurate need for short-term procurement for the state of Rajasthan. Learning's of various decision-making model for procurement from literature is also noted.

Chapter 4 This chapter includes the numerical mathematical modeling equation along with its constraint, its assumption and data analysis procedure of the present study.

Chapter 5 Explains the results obtained in this research. Both the numerical excel based and model-based results have been presented with listing the advantage of model formulation and it technical and pratical importance for short term power procurement for the state of Rajasthan.The various case scenario of lowest, highest,and a comparative analysis with merit order excel based calculation is done. Further annual cost based analysis is predicted along with the individual monthwise analysis with graphical representation.

Chapter 6 Summarized the important results and conclusions. Further more, suggestions for future work have been recommended.

Chapter-2 Short Term Market and Procurement Possibilities

2.1 Procurement Possibilities for the State of Rajasthan

The bulk electric power supply in Rajasthan is mainly tied to long-term contracts. The discoms who should provide electricity to their consumers mainly rely on supplies from these long-term contracts. Nevertheless, to meet the short-term requirements the market participants, short term trading plays an important role in such prevailing conditions [6].

Discoms have tied PPAs to meet their peak demand as well. The Discoms have to pay the capacity charge for this quantum even in the off-peak time.

Therefore, for optimum utilization, long term PPA from figure 2.1 should be only for base demand, and seasonal variations can be bought through other available market options.

From figure 2.1 ancillary services part of it is one of the four basic corner stones of electrical engineering. Supplemental services are support services to maintain the integrity of the power system and support their primary function of delivering power to customers. The system operator uses these over a number of different times to maintain the required balance and continuous consistency between compiler and load [7,8].

Equipment operation services consists of the services required for (a) load-balancing maintenance (frequency control); (b) energy storage and operational efficiency; and (c) maintaining storage and distribution facilities. Generally, auxiliary services are provided by integrated packaging materials and energy delivery services. With the seamless rollout of integrated upstream services, the increased participation of private organizations and the competition presented in energy markets, there is an increasing need for such services, to ensure reliable and secure grid performance [9].

After the day preceding the start of figure 2.1, the need for internal day energy, as well as system inequalities, is usually controlled by means of the deviation of resolution (DSM) and auxiliary (AS) mechanism servies [10]. Alternatively, the power exchange also uses an intra-day market power signal (which is based on continuous trading) which is additional to manage power imbalances in real-time by way of updating the system (four-time blocks) before actual delivery. Generators can modify the schedule itself; as well as discoms, close to real time (time / hour blocks ahead) to handle real-time imbalances, and there is no financial credit for such updates.

2.2. Power Supply Position Driven Motivation for Short Term Planning

2.1.1 Shortage of power leads to higher power purchase cost during peak demand

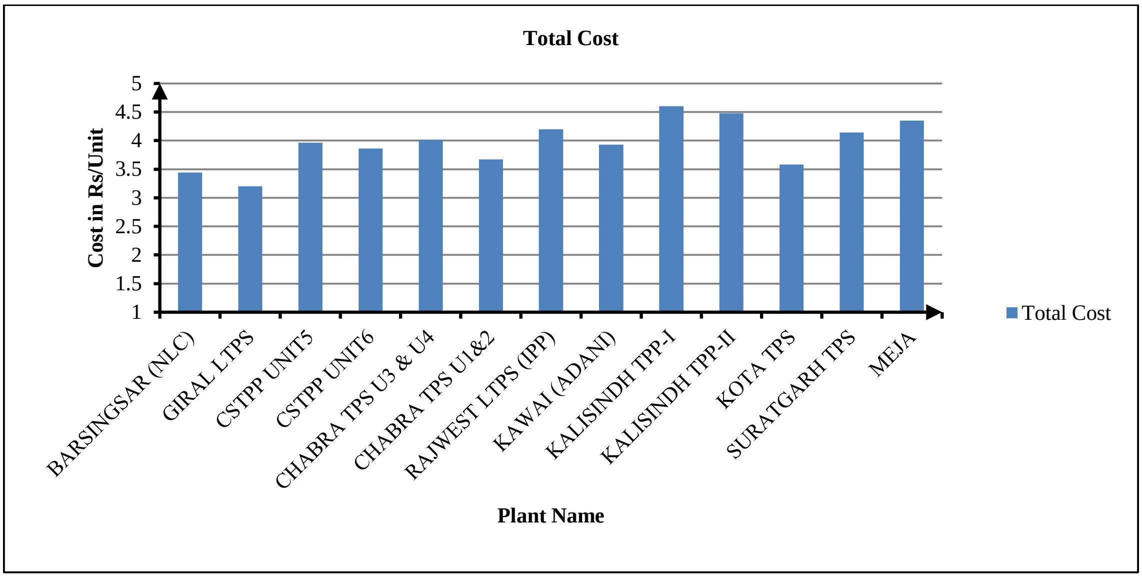


Figure 2-1 Graph Depicting the Total Cost per Unit from Sate Generating Plant of Rajasthan

In figure 2.2 we found that if some of the self-generating plants are operated to meet the short term requirement of the load then the total cost (fixed+variable) of such plant is some times higher than the per unit of power from the exchange. Keeping this in mind and growing in demand for energy in the future, the resource must enter into the PPAs of a variety of suppliers some of which are very expensive [11,12].

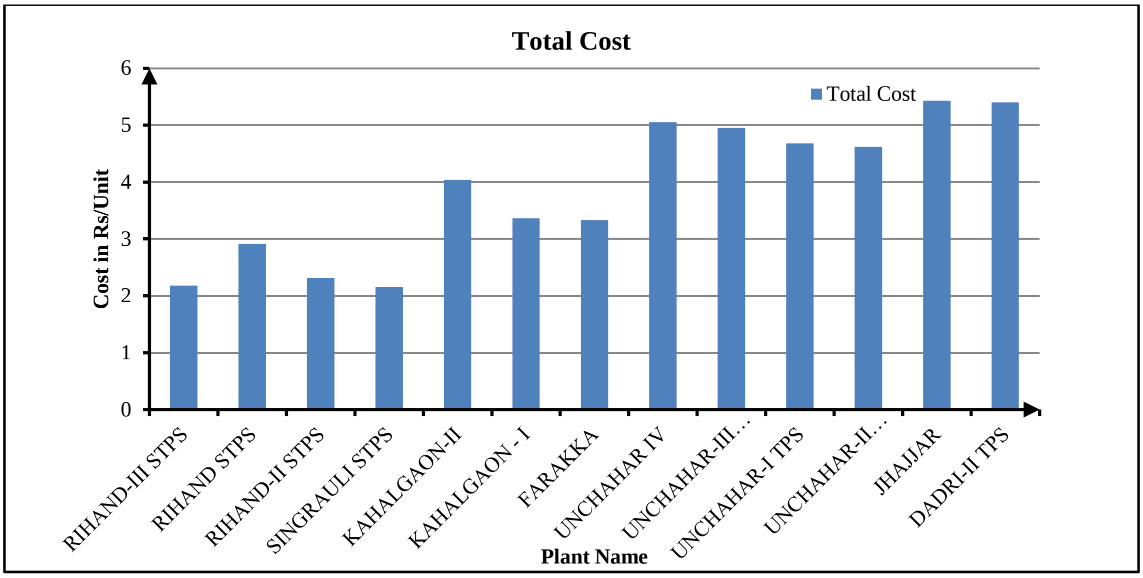


Figure 2-2 Graph Depicting the Total Cost per Unit from Central ISGS Generating Plant

Some of the central and central heating costs of ISGS are higher than the exchange rate. Payment of the fees to the most expensive creators even though there is no fixed capacity.

In an ideal situation, a distribution device would not like to gain power from expensive and reliable sources of information. However, the amount ofenergy available from the long-term and medium-term source of PPA often failed to meet the end consumer demand in the real-life setting. Therefore, consumption should be dependent on a change of power to meet the sudden demand limits on the day's planning and future.

If the spike in energy demand over time exceeds the amount of energy normally purchased from power switches under normal conditions, thecost of each risk received from day-to-day and ahead-of-time options becomes much higher. Therefore, use requires a great deal of discretion while taking power under the above conditions

However, it poses unique operational challenges to the delivery function. The major operational challenge is the uncertainty in the power supply, as it becomes partly sensitive to the transmission

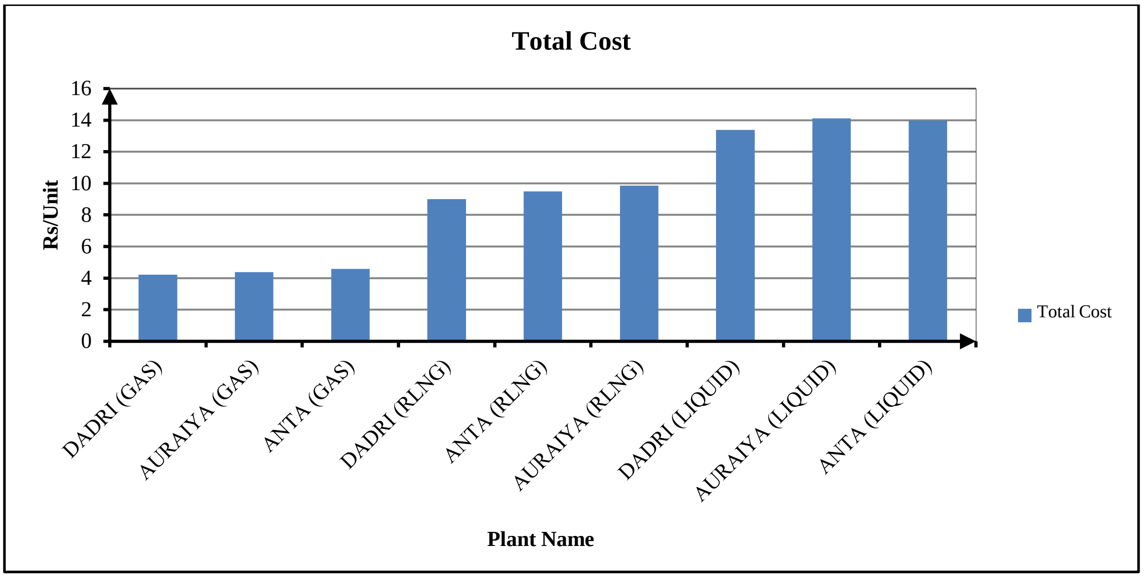


Figure 2-3 Graph Depicting the Total Cost per Unit from Central ISGS Gas Generating Plant

Some of the gas central ISGS gas plants in figure 2.4 has a higher total cost than power exchange price because of both high fixed and variable cost.If such a plant is operated to meet the sudden demand for a very short time then the main factor is the availability of fuel and then the total cost per unit is also higher so it can be avoided if possible and such demand can be fulfilled through other best option like short term market.

2.2.1 Power exchange cheap power utilization

For eg: Buyer

@132kV, 700MW, 8hr

IEX Price Rs/Unit: 3.2

Landed cost: Rs7.14/kWh

Under long, term PPA two components

- Capacity charges (commitment charges): Paid irrespective of whether Discom purchases power from these plants or not.
- Energy charges: Paid corresponding to the number of units of power purchased from that particular plant.
- If any how we can manage our procurement which a such a strategy that the utility

is primarily responsible for providing an uninterrupted supply of power to the end consumers. Keeping this in mind and increasing the demand of power in the future, the utility has to enter into PPAs with a wide range of suppliers some of which are quite expensive.

- So for optimum utilization, long term PPA should be only for base demand and seasonal variations should be bought through other available market options discoms plan their power procurement based on demand forecasts several years into the future to minimize overall costs. The movement of large consumers back and forth between supply from the discom and the market results in large swings in load for the discom. This creates considerable uncertainty for the discom in predicting the demand for power. The uncertainty, in turn, increases the risk for the discom in that the amount of electricity it purchases will be either too much or too little. As the discom tries to reduce this risk, the cost of procurement of power increases [12]

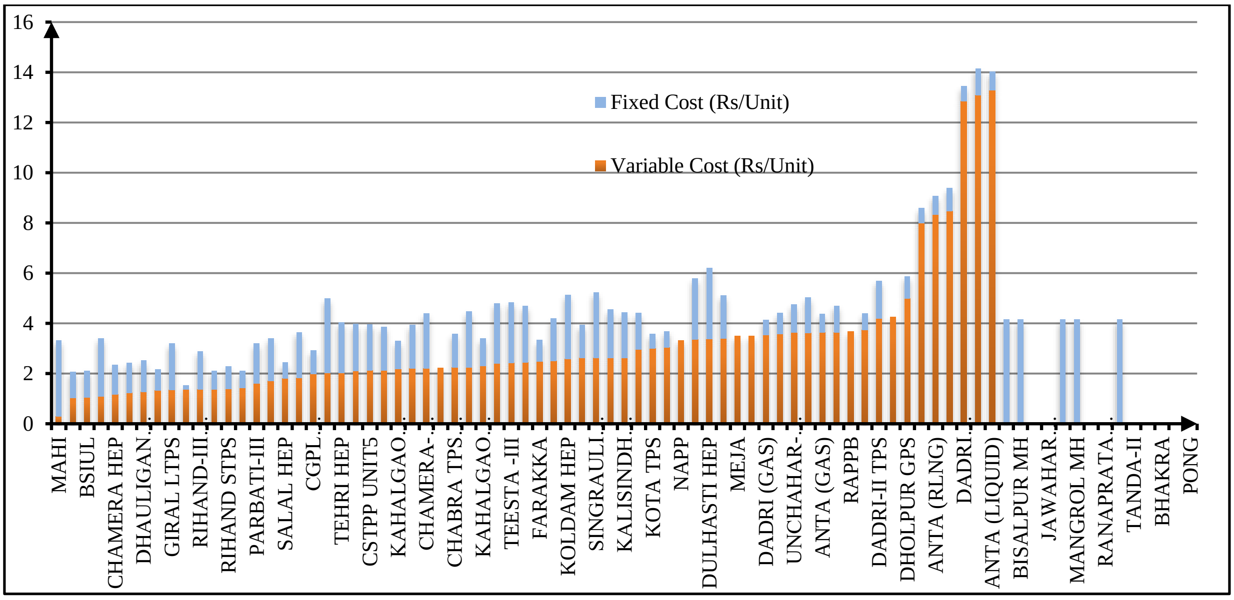


Figure 2-4 Graph Depicting the PlantWise Fixed and Variable Cost per Unit

- When the energy charge of the power plant is greater than exchange rates those plant should not be started to meet the certain demand hike period. During night hours, prices in the DAM are very low and savings can be enhanced if possible.

- The unit cost of powerunder long-term PPAs has a wide range. From figure 2.5 it varies from as low as Rs 1.54 per unit to as high as Rs 14.16 per unit,which remains the same during the period of agreement between suppliers and the distribution utility.From the figure 2.5 we can note the component of fixed and variable cost and in some of the noted plant the variable cost is nearly as high as nearly double or even more the cost of power available from exchange. So thepower planning should have such a methodology that it can overcome the loop hole of power procurement planning with better compliance between PPA and requirement of base demand.

- In this context, equilibrium-supporting prices means that so long as the generation mix is socially optimal (*e.g.*, a least-cost mix), all generators fully recover their fixed and variable costs through energy revenues. Otherwise, if thegeneration mix is not socially optimal some generators will not recover their costs (incentivizing their exit from the market) and others will earn positive profits (incentivizing entry of those technologies). Market exit and entry should continue in this fashion until the generation mixand prices reach a zero-profit equilibrium, which corresponds to a socially optimal mix

- To calculate the extent of optimization possible, we have considered the day-ahead declared capacity of the generators (State, Central, IPPs) and the actual dispatch. The difference of both suggests the scope of optimization for each of the generator.

- Any possible schedule revisions until intra-day time, which may result in lowering of availability of these generators and subsequent reduction in scope of optimization

2.2.2 Growing renewable penetration increases uncertainties for long term/baseload procurement

Increasing penetration of renewable energy and generation mix has the potential of negatively up setting system operations and planning processes unless it is complemented by a market re-design which aids this integration and brings the best possible efficient way without effecting the system stability. Real-time wind and solar vailability are weather-dependent, uncertain, and variable [13].

Another problem associated with the use of renewable resources is that they can increase the ramp in the net load profile (i.e., demand less more renewable output). This effect of renewable generation can increase the need for flexible dispatchable resources that can ramp their output up and down quickly. This can also result in over-generation' situations, in which the system must curtail the output of renewable generators to maintain load balance.This what we can notice in the next subheading where the statistics of such curtailment is well explained. These realities, combined with renewable generation technologies becoming cost-competitive with conventional alternatives[14].

Wind and solar generation curtailment of Rajasthan 19

Curtailment levels indicate how efficiently renewable energy is integrated. Large amounts of curtailments signal in flexibility in the system, preventing grid operators from being able to take full advantage of the available renewable resource [15].

Rajasthan has the largest percentage of renewable capacity outside the Southern region. Coordinated planning between intrastate transmission and locations of new renewable resources or plant can alleviate the risk of renewable energy curtailment. Sufficient transmission will be necessary to not only evacuate renewableenergy but also enable the full use of flexible resources such as coal or hydro [16].

2.2.3 Fuel shortages (Gas and Coal)

The fuel shortage is one of the major concernsareason as now depletion of such fuel due to a natural imbalance in geographical region as now coal is reserved for the plant who are entitled to generate under a long term PPA [17].

Looking for prospects the government has made such norms to preserve such fuel and utilize it efficient and effective manner.

2.2.4 Delay in commissioning of power projects

New unit commitment or addition of units plays an important role to meet the future demand. Completion of such projects in time can show a positive effect in procurement planning

2.2.5 The lower level of hydro generation

- Low hydro availability in Rajasthan limits its effectiveness in helping to balance changes to net load [18].
- Hydro plants follow a more pronounced two-peak generation profile due to availability of solar power during the middle of the day.

2.2.6 Transmission congestion at different levels:

Broadly, these regions are divided in terms of transmission:

- Interregional (e.g. WR to NR, Rest of India to SR)
- Intraregional (e.g. S1 to S2, N3 Import, W3 Export) and
- Intrastate (e.g. Gurgaon Import in Haryana, NPCL Import in UP, PGVCL to UGVCL in Gujarat, Etc.)

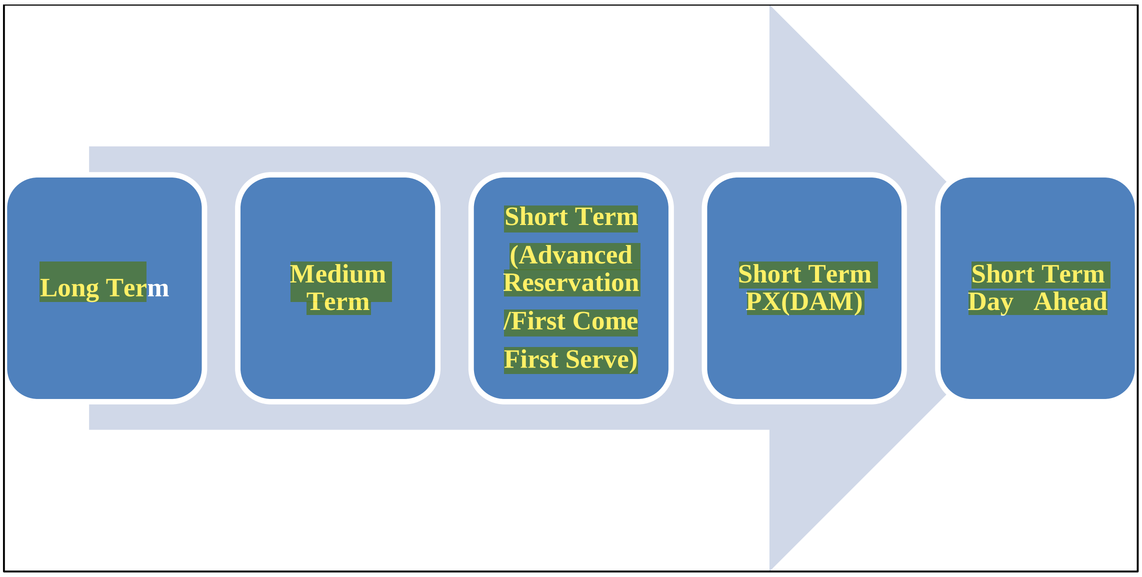


Figure 2-5 Transmission Priority

In this diagram as shown in figure 2.5 depicts the priority set for the transmission across the network. As we know the long term PPA are taking concern of major percentage of demand across India.All the transmission network are designed or laid as per the requirement of furure requirement of incremental load so to fulfill the baseload demand long term ppa are the first and fore most utilizers of transmission network.

Then comes the priority of medium term contract in which the remaning portion of the demand can be fulfilled through it.The percentage requirement is less than the long term ppa so it is been placed second on the priority list of allocation of transmission network.Similarly the next is short term in which advance reservation can be done for the transmission network against the certain quantam of power requirement in advance and therefore its like first come first serve as shown in the figure 2.5.The fourth priority is given to short term day ahead which is handled through the power exchange market in which the multiple buyers and sellers come and purchase certain quantam of power for a dayahead requirement and so this is been last one to get priority in the transmission network.

2.3 Example-Based Various Procurement Analysis of Rajasthan

The current state of procurement in Rajasthan for a better understanding the analysis is done for a particular day.

The distribution system has to contend with two broad problems while gaining power from many suppliers and exchanges of energy: uncertainty in energy delivery and energy cost. It is desirable from a distribution perspective to have less uncertainty in the supply of uninterrupted power supply to end consumers. At the same time, it is also prudent on a distributed part of the distribution to meet a large chunk of its demand by obtaining a large amount of energy at a very low cost. Variations in the amount of energy available under PPAs are expressed in terms of the maximum power density and the minimum distribution.

The generation and various procurement sources are shown through various graphs.The main aim is to fulfill the demand and the curve of demand-supply should be matched at any instant of time .if we look from the generation side then we conclude that for a particular day the state generation had a major contribution in every time slot.Whereas the generation or the procurement from central ISGS nearly remained the same throughout the every time slot of the day the best possible reason for such constant generation or procurement for a day or certain period of can be due to the long term PPA which might or have a prescribed quantum of power for that period of time.It was further observed that the procurement from other ISGS has been quite constant for the longer duration of the year as it was noticed from the data of the merit order dispatch website of India.

Uncertainty in power supply from pre-planning and forecasts is very high and has no pre-disclosed range so the power exchange offering is under Rajasthan status, and the prospect of such a power exchange can lead to better and cheaper power to meet unstable demand as discussed earlier in chapter 2.

In addition, the nature of the bilateral contract was almost the same throughout the day as it remains critical because of its contractual agreement. The possible reason for the above scenario could be attributed to the close use of long-term electricity available by the majority of suppliers. Therefore, more needs to be met from the choice of energy exchange market. After meeting the growing demand for energy, if more power is available for a certain time of day as renewable generation increases during the day and comparisons are smaller and more efficient, such additional power sales can lead to an increase in sales revenue.

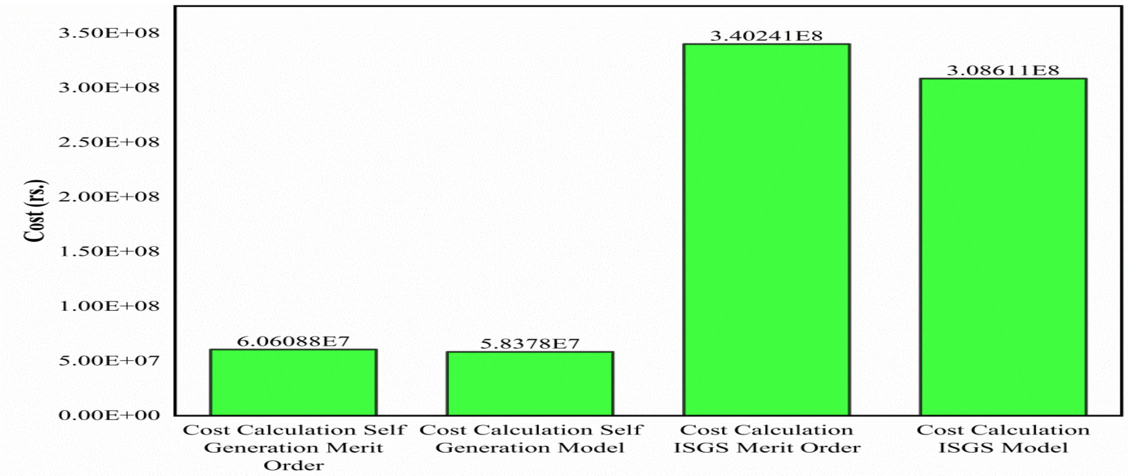


Figure 2-6 Graph Representing the Various Procurement Source and Their Price in Rajasthan for One Day.

In the above graph of figure 2.9, it shows the energy procurement in MWh from various source throughout the day and its price based on both fixed and variable cost. In an ideal situation, the state distribution utility would not like to procure power from expensive and uncertain sources of supply. However, the volume of power procured from astable source of long-term and medium-term PPAs. Most of the time fail to meet the demand of end consumers in a real-life scenario and prefer load shedding. Thus, the quantum of energy purchased by the utility through power exchange for meeting the sudden spikes in demand through day-ahead is insignificant as there is a gap in between the demand and the total generation as shown in figure 2.8.

2.4 Research Gap

Looking at the gap between demand and the supply from capacity tied up under longterm contracts of utilities will continue to be insufficient to serve the entire demand across various time blocks for the state of Rajasthan.The state continues to depend on peak load power plants, typically gas-based or diesel-based–close to load centers for meeting their deficit peak and uncertain demand increase. To summarize, the short term market is still to achieve its full potential.Analysis from graph 2.8 and 2.9 it is found that the selling potential of around 10.20%at block level for the period where generation is higher than demand.

This potential is muted, as it does take into consideration the load shedding during peak hours demand.The potential size of the short term markets should be increased;thus highlighting the huge untapped potential and an opportunity of further development of the short term power markets in the state as this would lead one to find and invest the suitable prices for procurement from short term markets for meeting their power needs on a real-time basis. In this context, power exchanges would continue to play an important role going forward.Finally, we could not find any studies, which have developed a framework of power procurement for a distribution utility based on the analysis of real time data. Thus, there exist considerable research gaps in the sphere of power procurement by a power distribution utility.

2.5 Objective

Further, when the availability of power under both long-term PPAs and day-ahead and term-ahead options varies, the power procurement plan suggested by the model also varies. Thus,there is a need to develop a power procurement framework, which would provide the distribution utility,and other power procurement supplier and producer broad guidelines in respect of procuring power from different sources under different scenario.

3.1 Short Term Procurement Classification

<table>
<tr><td colspan="2"></td></tr>
<tr><td rowspan="6">Day Ahead Scheduling</td><td>Long Term (12 – 25 years)
Through Power Purchase Agreements</td></tr>
<tr><td>Medium Term (up to 5 years)</td></tr>
<tr><td>Short Term Advanced / First Come First Serve Transaction</td></tr>
<tr><td>Short Term Day Ahead Bilateral</td></tr>
<tr><td>Short Term Day Ahead Market (PX)</td></tr>
<tr><td>Short Term Day Ahead Contingency (PX)</td></tr>
<tr><td rowspan="4">Real time</td><td>Real Time DSM / AS</td></tr>
<tr><td>Real Time Intra-Day Contingency Transaction</td></tr>
<tr><td>Real Time Intra-Day Market (PX)</td></tr>
<tr><td>Real Time Re-scheduling</td></tr>
</table>

Figure 3-1Block Diagram for Power Procurement Planning, Scheduling & Dispatch

Generation, transmitand other cap assets are created much earlier than the time and place for distribution companies (Discoms) to plan their energy purchases. Electrical market design also requires the functionality you need to ensure that the performance goals of the system (to maintain system security) and the energy market performance (energy consumption at the most cost effective) are well aligned and illustrated in a consistent way. Purchase of energy purchases (long term, medium term and short term). Long-term contracts are entered into with supply chain agreements (PPAs) for a period of up to 25 years. Long-term contracts constitute 90% and make up the largest share of energy purchases for discoms and the remaining portion meets long-term andshort-term contracts.

Most of the contracts in India are tangible environmental contracts and in the future, the discoms arrange themselves based on such contractual agreements. This means that on the preceding day, the discoms specify the amount of energy required to be programmed into the power station you have entered into or is responsible for in the contract, and the fixed price of energy under such long-term contracts is kept hidden. Approximately 90% of the planning day is based on this planning process. The remaining 10%, sold by retailers, directly between the discoms and on the exchange of power. There is another optional window for planning for a future exchange of energy exchanges but its share is probably less favorable at present [14,20].

Subsequent to the pre-planning dayas describedabove, the need for internal day strengths and system inequalities is usually controlled by means of the deviation of resolution (DSM) and auxiliary systems (AS). In addition, the exchange of power also applies to the internal energy market (basedon ongoing trade) but it is not easyenough as of yet. One way to control real-time power imbalances is to review the system (four-time blocks) beforethe actual trip. Generators can update itself; so discoms can also do the same, this allows each participant to approach real-time switches (four time blocks / hour earlier) to manage their real-time imbalances, and this schedule review process has proven to be beneficial as there is no financial debt for such review [20].

3.1.1 Benefits of short term market:

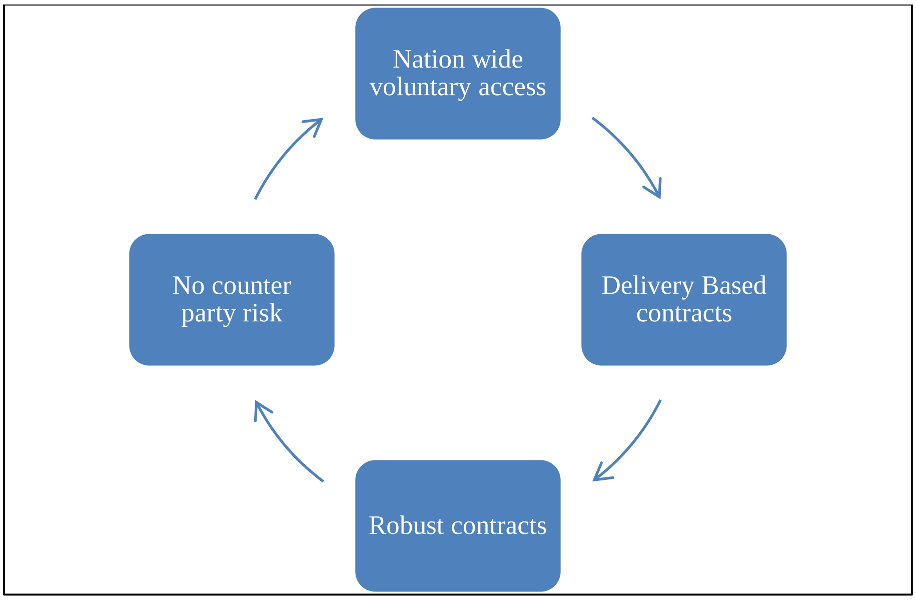


Figure 3.2 Figure depicting the benefits of short term market in India.

In the above figure 3.2 we get a best insight of short term market benefits where nation wide voluntary access is permitted without any discrimination further this access nutured the contract to be a delivery based which enhances the characteristic of such contract to be robust and versatile in nature.In additioin to this the most advantageous is the least risk on both side of the contract .

3.2 Challenges Hindering the Growth of Short Term Planning

This has been reminded that the short-term market has great potential and importance in terms of India's current demand. In the meantime, if we look at some of the earlier considerations it is found that there is an extended capacity that goes through there and has more power than that which remains unchanged in the exchange. The cost of acquiring this energy and using all the energy that is not accessible to the system can be optimized by working effectively with this market [21].

In addition, the short-term market helps to compete in the market place and is a foundational pillar of achieving the objectives of the Electricity Act of 2003 [1]

However, there are several barriers to the successful launch of the short-term market and it is worth pointing out some of these barriers that hinder the growth of temporary markets in India. In the following sections, these challenges have been analyzed as [3,21]:

1. Authoritarian Challenges
2. Institutional Challenges
3. Infrastructural Challenges and
4. OperationalChallenges

3.1.1 Regulatory Challenges

As per the Ministry of Power, if a consumer wants to avail the benefit of the option to buy power from competing sources, then the discoms do not have an obligation to compulsorily supply power to such consumers.

This puts the open access consumer in a dilemma, in case the transmission network on which the power flows breaks down or if the generator, from where the open access consumer receives electricity fails to generate power. Both the events are out of the control of the open access consumer and would typically fall under the force penalty category. Which is and has tobe obliged by everyone in a true sense [21].Since such obligation and its ground-level implication can hold the ease of conducting theopen-access market efficiently and effectively with transparency too.

3.1.2 Institutional Challenges

Resistance of licensee: It is been prominent and well understood from some past scenerio that the distribution licensee usually hesitates to implement open access very often as they have the fearof losing their high paying industrial consumers with prime importance to serve them because they are who cross-subsidize both the agriculture and domestic consumers.

3.1.3 Infrastructural Challenges

Absence of dedicated feeders: Open accesscan be assured only if there are separate feeder lines. However, most of the present-day network has meshed with embedded consumers (non-open access consumers). In the event of load shedding by distribution licensee for a feeder where both open access consumers and mixed type consumers (non-open access consumers) are connected.

As per the norms, the independent feeder shall be permissible to the consumers opting for open access capacity upto which SERC has introduced open access and are connected through an independent feeder. Further, then on independent feeder should supply to such consumers of open access subject to the condition that they agree to foster restrictions imposed by the utility on the feeders serving them [21].

3.1.4 Operational challenges

The different outfitted challenges faced by a consumer are given below.

Uncertainty with respect to dispatch: A good number of consumers who is a regular purchaser from short term market, who normally procure power from the DAM faceses the major problem like a high level of uncertainty in terms of scheduling and planning of their respective power purchase due to limited ease of use of transmission network. As the long term and medium-term contracts have greater priority and approval of transmission at sipulated predecided levels. Besides this, any deviation from the scheduled drawl or injection will have financial implications on the open access consumers, in terms of unscheduled inter change charges.

Unpredictability of charges: There exists senselessnesss prospect in regard of to open access charges. Some states like West Bengal and Tamil Nadu have cross-subsidy surcharges that are too high in comparison to other states.The Tariff Policy2006 has provided a formula for the determination of cross-subsidy surcharge, however this monopoly of certain states as mentioned.The respective state commissions in such state have either altered with the formula or put additional conditions for the computation of cross-subsidy surcharge as per their suitable it prospective.Besides that, there is no defined predictability about the level of future open access charges that has to be leived with thus,making consumers reluctant to avail of this service.The act was proposed fora gradual reduction of cross subsidy surcharge, but no such reduction path is found in any of the states.

Need for accurate short term procurement:

The need for short term purchases Challenges on the demand side include fluctuations in energy demand within a day, several days a week depending on days of the week or weekends and different months of the year. Predicting the demand for energy at different times within a day has major drawbacks and a matter of great concern because if there is a hole in the balance in that equation there is a huge loss.

More accurate measurements and demand calculations can guide to better performance and to furnish and make sure consumer fulfillment on the other. Challenges in the deliver side supply chain include the ability to access a large number of suppliers including thermal power stations, turbine plants, nuclear power stations, solar power stations, etc., which are available nation wide. The state should negotiate with these manufacturers and, ultimately, enter into an agreement on their energy supply. The type of contracts include long-term, medium, and short-term contracts with a different time zone in each case. The unit cost of energy charged by various manufacturers under different types of contracts shows that they vary depending on supply sources and many other technical and operational factors. Purchasing costs reflect a slightly different trend for different manufacturers. Under such disparities, consumption should enter into agreement with multiple manufacturers at the same time to obtain maximum capacity for them

3.3 Literature review based on various model of optimization

Energy management manuals are best done with the use of domain optimization models in the context of energy cost efficiency, risk reduction of variable costs, project expansion, etc.

Woo et al. (2006) : In this paper it has established that a local company (LDC) living in Pacific in the Northwest is endemic and often relies on various sources of procurement such as spot markets, pre-contracts,and long-term purchase agreements for electricity to meet. customer need to reduce variations in purchase costs. They worked extensively on the problem and developed a model tool for statistical ordering so that they could find the leading leads that could best allocate potential leads and sells existing LDCs between acquisition costs and expected costs [22].

Hatami et al. (2009): In this paper a stochastic integrated regression model was developed to determine the optimal selling price and purchase strategies for an electrician based on the Iranian electricity market. They have considered or opted for at rade-off between theexpected increase in performance and the risk reduction of burnout [23].

Yau et al. (2011): In this paper a two-stage unstructured two-stage programming model can be used by a custom contract supplier with a variety of time and custom contracting capabilities to meet individual contract obligations under local price uncertainty [24].

Beraldi et al. (2011): In this paper they have produced a cost effective acquisition plan for a large Italian-based consumer to reduce the cost of procurement and exclusions excluded from other previous publications including this risk related to budgetary constraints which, if followed, will result in significant financial losses. The program also outlined the amount of energy that will be gained through bilateral contracts and the emerging electricity market [25].

Jirutitijaroen et al. (2013): In this book a robust planning model and detailed methods have been adopted by a power company that helped and helped the company determine how much fuel was obtained through various and affordable contracts. [26]

Zhang et al. (2016) In this paper further advances were identified and developed an integrated stochastic integrated model for energy storage units where production planning concerns and energy efficiency approaches and their problems are strong. [27]

Beraldiet al. This approach and its outcome provides decision-makers and market players with an appropriate strategy according to their needs that meet the energy requirements with high reliability and efficiency. Alternatively, this method includes a conditional value that is at risk of reducing potential losses.

Hu et al., Najafi et al. (2018): In this paper books bought under long-term and medium-term contracts generally or in excess do not meet the demand. Because as we discussed earlier also that the main challenge facing the distribution function or companies is to ensure that uninterrupted electricity is provided to the end users or consumers. Some times a distribution function must purchase additional energy from a high energy exchange at a very short notice, often referred to as an immediate or future purchase to meet the demanded space. The cost of energy acquisition costs up to a certain percentage of the daily operating cost. In addition, a small percentage of the reduction in purchase costs may result in an expected saving on total purchase costs. [29]

However, this method does not guarantee a low cost. This has prompted us to view this problem as a multi-dimensional barrier to energy acquisition and the creation of a cost-effective model to reduce the cost of electricity procurement. The above scenario encouraged us to design a framework for the procurement of electricity

Although there are significant content for the literature on different frames of modelling and mathematical models and the use of advanced monetization models for the work of companies or companies, cost reductions of major consumer electronics or distributors, etc. , in a recent study few have looked at or encountered in this study to be able to use the cost of purchasing a suitable power transmission system in the Indian context. Many processes are used for free control domains. Besides, the economic viability of procurement agreements (PPAs) intervened between manufacturers and distributors while the acquisition of a complete procurement system has not been extensively investigated.

Chapter-4 Model Formulation

The mixed integer programming (MIP) model is designed with a motive to minimize the total daily power procurement cost. It is optimisation model with linear power equations in every segment of various purchase options.The existing PPAs during that period of time from state generation and as well as from central ISGS generators.The cost is calculated with simple excel based linear equation as used in model and cost comparion is with the cost based on model simulation.In addition to this appropriate volume in every time slot is found for a particular day. In second part various scenario are taken into account of short term market to take in account the volumes to be bought from day-ahead and term-ahead options are recourse options.

Assumptions

- Demand was taken in 15 min block from the utility and assuming it to be the same demand to be projected by the state to NLDC
- Fixed cost and variable cost of power was estimated on a daily basis from the merit order dispatch annual fixed cost of power to be paid to the suppliers under PPAs for ending out the total daily power procurement cost.
- Fixed cost and variable cost of power from self state generating plant was estimated on a daily basis from the merit order dispatch.
- Schedulcled capacity, maximum plant capacity, type of generating unit, ownership and percentage allocated to state under central isgs plant are made accessible from merit order data.
- The ramp and ramp down of all thermal generators of state are taken as 1MW/minute.
- The minimum power constraint is assumed to be 45% of maximum power rating of individual generator as per technical minimum operation.
- The average pool price for day ahead market in 96 time slot (24 hrs) is taken from iex data historical archive.
- The average pool price for term ahead market is assumed to be

Rs3000/MWh.

- The number of bilateral contract is assumed to be five for the state of Rajasthan .The rate of all bilateral contract is assumed to be Rs3000/MWh,and other variation are done to to note the sensitivity of bilateral contract on the overall price and individual contribution of bilateral contract in such scenario when such factors are reduced or increased.
- The renewable generation data is also considered in 15 min block, which is pool generation data from utility.
- The state of Rajasthan is rich in renewable generation so it is assumed that the renewable power purchase obligation is fulfilled by its self-renewable generating capability.Further it noted that all renewable plants are must run plant.No renewable curtailment is been addressed in this model.
- Further, the assessment of contract price of power was also made based on observation of past data of the utility.
- Maximum and minimum volumes of power available from each supplier under PPAs remain fixed. The maximum and minimum power limit of each generator is considered as per present technical minimum operation.

Description of the problem

Assuming the produced and the provided power is treated as a fixed within a quarter hour basis

Let T be a set of quarter hour

T $=\{1, \ldots . N^{T}=96\}$

Assuming we are given the forecast of electric power for all 96 quarter hour time interval per day.

Constraint associated with power plant:

p_{max}=maximum power in MW.

Assuming technical minimum operation=45%

Therefore, p_t=amount of power in MW of the power plant at a time period t.

So

$$p_{t \geq 0.45} p_{max} \qquad \forall t$$

Cost of Self-Plant Generation:

Generation cost in the time-period *T* is given by

$Cself_{i,t} = (fixed\ cost)i + \sum_{t=1}^{T} ai\left(Pself_{i,t}\right) * v_{i,t}$.............. (1)

Operating constraints of the generation unit is given as:

$Pself^{min} v_{t,i} \leq Pself_{t,i} \leq Pself^{max} v_{t,i}$............. (2)

Ramping limits for the generation unit is expressed as:

$Pself_t - Pself_{t-1} \leq ramp^{up} v_{t,i}$................. (3)

$Pself_{t-1} - Pself_t \leq ramp^{dw} v_{t,i}$................. (4)

$Pself_{t,i}$ = Self-generated power at time *t*

$v_{t,i}$= One if unit is on otherwise zero

a_i=Variable cost of i^{th}unit in Rs/Mwh

Power from Long PPA Contract

Total cost of power purchased from long term PPA in the time T

$C_{ppa,t,i} = [(fixedcost)i + \sum_{t=1}^{T} bi\left(Pppa_{t,i}\right)]u_{t,i}$............. (5)

$Pppa^{min} u_{t,i} \leq Pppa_{t,i} \leq Pppa^{max} u_{t,i}$............... (6)

$u_{t,i}$= One if any particular PPA is selected or otherwise 0

b_i =Variable cost of i^{th}unit in Rs/Mwh

$P_{ppa,t,i}$ =Power purchased from the contract

P_{fix} =Fixed purchased power

Cost of power from spot market:

Total cost of power purchase from spot market in time- period T can be calculated as:

$$C_{stm=} \sum_{t=1}^{T} \lambda_{t,iavg} \,(P_{t,}^{stm} dam) + \sum_{t=1}^{T} \lambda_{t,iavg} \,(P_{t,i}^{stm} tam) \ldots\ldots\ldots \quad (7)$$

$$P_{t,i}^{stm} tam \geq 0 \ldots\ldots\ldots\ldots\ldots \quad (8)$$

$$P_{t}^{stm} dam \geq 0 \ldots\ldots\ldots\ldots\ldots \quad (9)$$

C_{stm}= Power purchased from spot market at time t

Assuming that pool prices with an average of λ_{tavg}

$P_{t}^{stm} dam$ =Power purchased in day a head

$P_{t,i}^{stm} tam$= Power purchased in term a head

Cost of power from bilateral contract (Mto, Sto)

Total cost of buying from bilateral contracts, for time -period T is given by C_b

$$C_{bc} = \sum_{t=1}^{T} \lambda_b \, P_{b,k,t} \ldots\ldots\ldots\ldots\ldots \quad (10)$$

$$p^{b,min} k_t \leq P_{b,t} \leq p^{b,max} k_t \ldots\ldots\ldots \quad (11)$$

λ_b =Bilateral contract rate in Rs/MWh

$P_{b,t}$ =Power purchased through bilateral contract at time t.

With

$p^{b,min}$ = Minimum power purchase limit and

$p^{b,max}$= Maximum power purchase limit.

k_t = Binary variable, which is one if contract is selected, otherwise zero.

Renewable generation

$\{P_{wn} + P_{bo} + P_{hy}\} = P_{rew,t}$……………. (15)

$P_{rew,t} > 0$………….. (16)

$$P_{rew,t} \leq RPO\ P_T$$

$RPO\ P_T$ = the quantum of power to be purchased under RPO target for consumer under the planning period T.

Total cost of power procurement

Total cost of power procurement with UI charge in the given time period T is given as

$\boldsymbol{C_{total}} = \boldsymbol{C_{Ppa}} + \boldsymbol{C_{stm}} + \boldsymbol{C_{bc}} + \boldsymbol{C_{self}}$………….(17)

C_{self} =Generation cost in the time-period T is given by

C_{bc} =Total cost of power in bilateral contracts

C_{stm} =Total of power from short- term market

C_{Ppa} = Total cost of buying power from fix contract

Demand formulation

$P^{total} = P_{b,t} + P_{rew\ t} + P_{self\ i,t} + P_{ppa\ i,t} + P_{t,i}^{stm} tam$…….. (18)

$\sum_{t=1}^{T} P^{act} = P^{total}$……….. (19)

$P^{total,min} \leq P^{total}$ …….. (20)

P^{act} = Actual demand

P^{total} =Total power procurement

$P^{total,min}$ =Minimum power that the consumer can reduce

P_{bc} =Power through bilateral contract

P_{rew} =Power through renewable energy

P_{ppa} =Power through long-term ppa contract.

P_{self} =Power through own generation

Objectve function

Objective function considers a tradeoff between two opposite criteria, the procurement cost minimization and the risk minimization.

$\boldsymbol{C_{total}} \, \forall t \, P_{stm} \, ,P_b \, ,P_{rew} \, ,P_{pix} \, ,P_{self} \;\; , \; v_t \, ,u_t \, ,k_t$……… (21)

The elements of power procurement costs how nin the objective function from equation 20 and 21 areas follows:it includes the summation of all the cost like self generation cost, cost from bilateral contract, cost from long term agreement, and cost of power purchased from short term market including term ahead and day ahead.

The self and long-term generation cost from equation 1 and 5 are considered linear in nature with two components of fixed and variable cost, where the variable cost is the prime need to be optimized, as it is dependent on the quantum of power purchased as per the contract. The fixed cost component is remains static.[30]

Data analysis

- The demand data in 15 min block is segregated in to month wise average demand and the annual average demand is analyzed which revels the demand pattern across same time block. Further, the seasonal wise demand can also be plotted to address the procurement planning for that particular seasonal demand.

- The renewable daily generation data is also segregated into average generation of month wise and then into seasonal wise.

- The self-generation plant specification like declared capacity, scheduled capacity fixed, ramp up, ramp down, maximum and minimum power limit and variable cost are recorded from merit order dispatch.

- The central ISGS and the state generating plant which are considered or happened to be the generating unit under long term ppa their specification like declared capacity, scheduled capacity fixed, maximum and minimum power limit and variable cost are recorded from merit order dispatch .

- The average pool price for term ahead and day ahead are taken from past data from IEX exchange for the particular northern region (N2).
- Medium term bilateral contract data are taken from state sldc which includes scheduled dispatch and curtailment for last one year, variable cost assigned in contract.
- For one scenario theThe excel based calculation is done with the same linear equation of mathematical model as described in equation 1 and 7 in this chapter.
- The amount of power existing throughout the Power Exchange on an hourly basis with less than a day and pre-purchase purchases depends on the gap between demand along with supply and consequently do not remain stagnant. However, some estimates are made based on hourly availability under the date and future options based on examination of past data
- Findings in that defined range include the suitable quantity of energy received commencing various suppliers all the way through the PPAs and energy transfers added to the day before the various alternatives and the volume of energy sold under pre-arrangement. It also calculated the entire price of energy bought under the PPAs, the cost of energy intake or traded through exchange for energy under the day, the bilateral contract as well as many other options, which could provide rich management insight.

Chapter-5 Results and Discussion

The MIP mathematical formulation along with the model aimed to comprehend the best possible performance that a utility or large consumer can opt along with their current practice of power purchase pratice.In this formulation the important or key concern resources avability and their present structure of compliance is included with motive of best suited procurement methodology. Important parameters are selected for the above decision problem. Specifically, those structures are chosen over which the decision maker is limited or out of control. These include hourly energy demand, variable energy costs from various providers under long-term PPAs, daily energy costs under long-term PPAs and greater energy ease of use in pre-existing in addition to future options.

Cost sensitivity analysis:

For the same particular day demand 22 Sep 2019 the cost comparison was done considering to check the cost effective validation of the mathematical model is done. Considering the demand to be meeting by self state generating and central ISGS plant

The certain steps followed for excel based calculation:

For the same particular day data of number of scheduled generator, scheduled capacity, plant capacity, fixed cost and variable cost are retrieved from merit order archrival data set of every day.

The excel based calculation is done with the same linear equation of mathematical model as described in previous chapter. The maximum, minimum, ramp up, ramp down limit for such generator when used in model simulation are taken into effect as described in chapter -4

In effect of renewable generation is also taken in account for both the calculation based on excels and GAMS model.In the given below figure 5.1 graph the simulated Gams output result is shown which shows the cost comparison of both the case for both type of power procurement source for the utility.

The cost of excel based calculation turned out to higher than the model based cost it is oblivious because the excel based calculation is not been the optimized cost because it shows the stringent nature of PPA because the utility or the state has to bear the fixed cost and the event of making generation dynamic is not into proper synchronization. Where as in model based calculation the binary variable is used as a status indicator for the individual plant for both type of generating unit. This makes it dynamic in nature for every time slot with the optimal cost of procurement to be done.

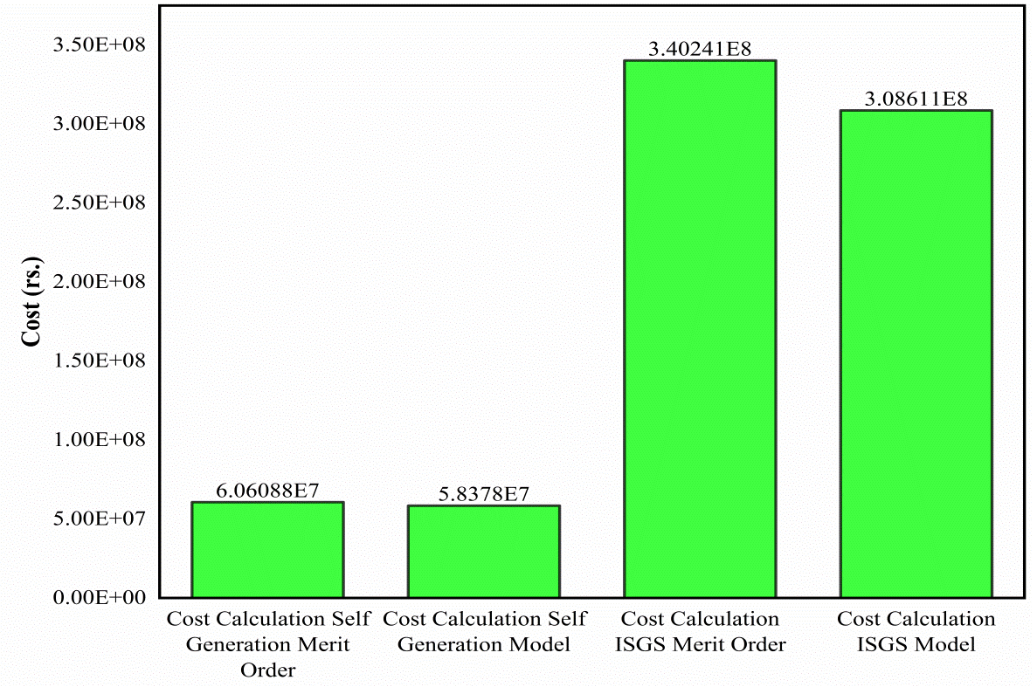


Figure 5-1 Variation of Power from Central ISGS in Various Time Slot

From the given figure 5.1 is been concluded that the percentage difference in cost from excel and model calculation is 0.17 crore rupees for self generating and 3.14 crore rupees per day which turn out to be significant amount if taken cumulative in yearly basis.

This very significant amount creates the huge impact on the overall energy cost for various types of end consumers.. The model suggests with the aim of the increased availabiliity of power at a some what economical rate from the selected suppliers under long-term agreement should be used to the maximum possible extent.

The figure 5.2 shown below depicts the demand and the generation from renewable and from other two sources.

The state generation remains constant as noted from figure 5.3 with same number of its generating unit in every time slot making it almost constant generation throughout the day. The generator with the least variable cost is selected by mathematical model formulation.

Whereas the number of central ISGS plant participation are more as compared to the state generating plant because they contribute cheaper variable cost component part as compared to the state generating plant.

The variation of power output from central ISGS plant from figure 5.3 is well coordinated along the renewable generation in time slot from t29 to t74 as the output from such plant are reduced or the other unit with prominent cheaper cost in the that particular time slot.

The number of central generation plant is five from figure 5.2 which are contributing in every time slot as they been the cheapest in every time block but Gno24,Gno21 and Gno22 are contributing in every time slot with their flexible ramp up and ramp down limit. Where as generator Gno20 is almost constant with no change in its generation output

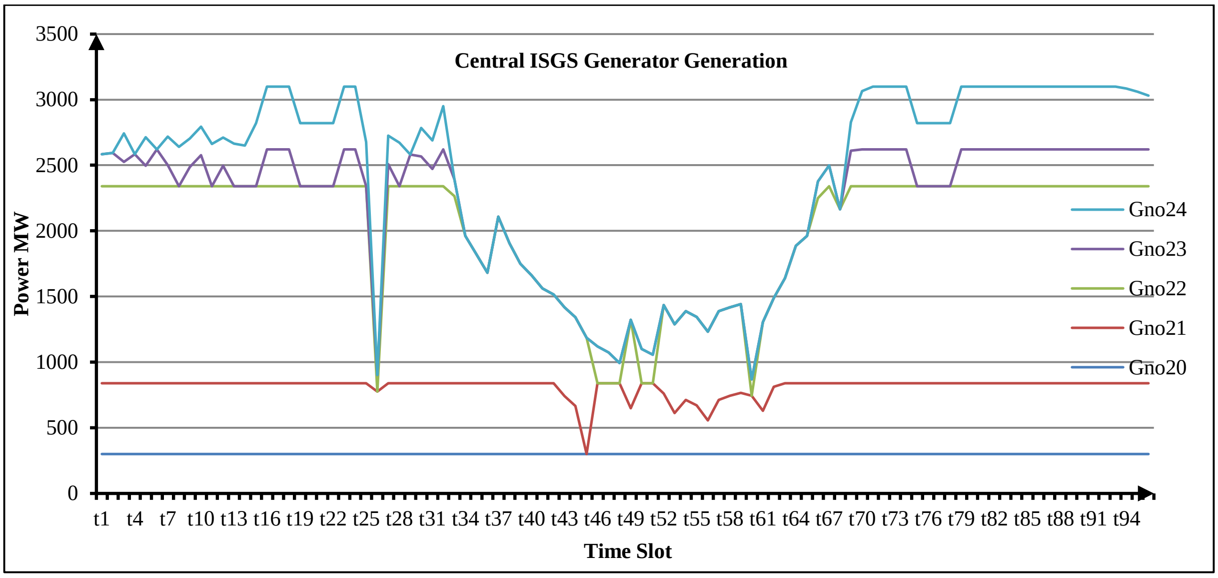
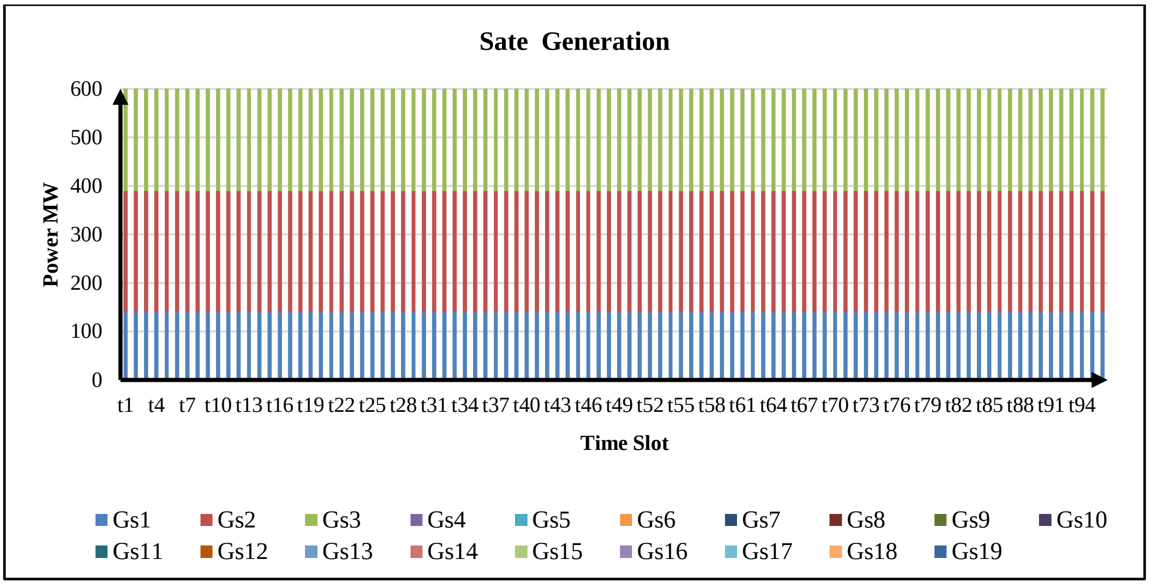


Figure 5-2 Variation of Power from Central ISGS in Various Time Slot



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In the perspective of state generation only generators Gs1, Gs2 and Gs3 are been cheapest in the entire time slot and therefore it is been only scheduled as per the model simulation result as shown in figure 5.3.

Similarly we can more precisely see in figure 5.4 that state generation is almost constant.

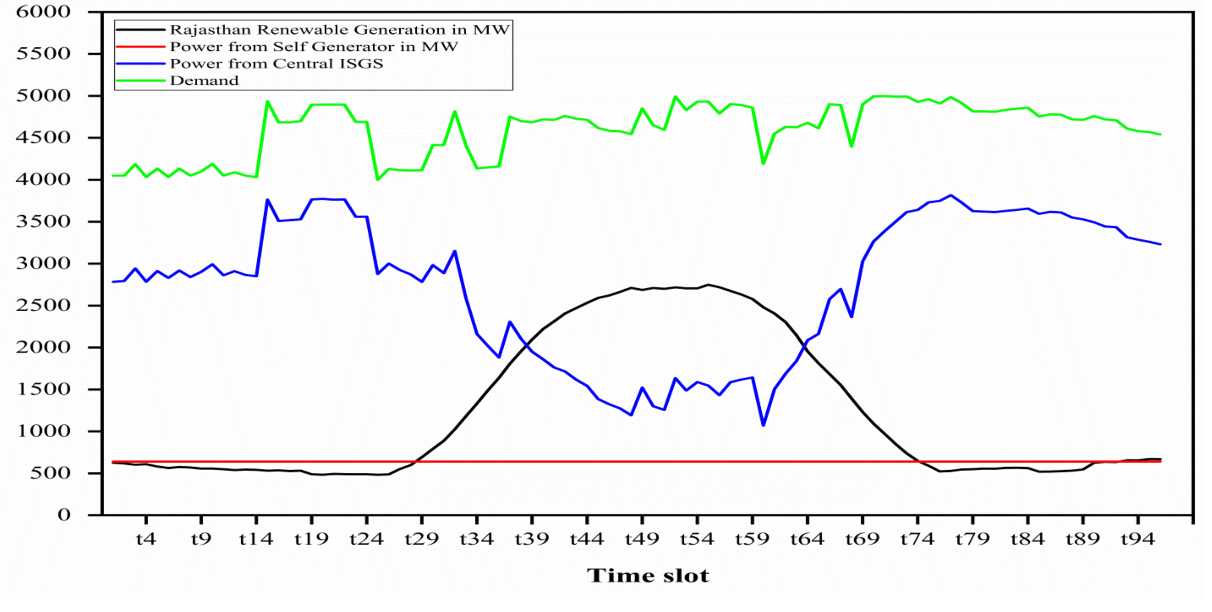

Figure 5-3Variation of Power from Various Source and Demand

Analysis with Participation of Short Term Exchange Market:

With the same demand and renewable generation the involvement of short term market and bilateral contract made by the state are taken into account. This scenario will be insightful to the participation of the short term market and to note the overall reduction in the cost and their individual procurement cost from various sources.

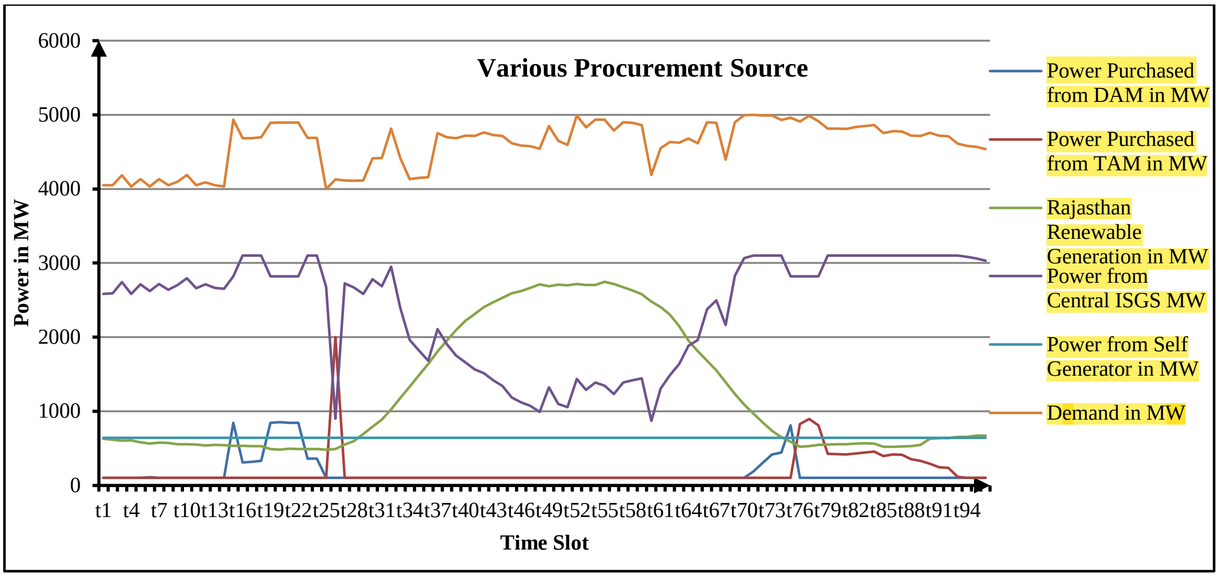

Figure 5-4 Power from Various Sources Including Short Term Market

From above figure 5.5 it is noted that the state generation and procurement from it remain same with no variation in power with the same state generating plant scheduled as in the previous case in figure 5.3

There is a variation in power procurement from the central ISGS plant along the same number of generating unit as in previous case and some new procurement option with addition or commitment of new unit with optimized cost in various time slots due the influence of market participation of TAM and DAM.

There was no influence of the various bilateral contract was noted in this scenario as it was taken in account. Therefore no power is been purchased or procured through bilateral contract as its cost was considered constant all throughout the period and as inferred through the model result analysis it did not suggested to procure from such contract due it higher Rs/MWh cost as cheaper option was available through short term market.

The variation of power procurement from day a head is well noted in t6, t16 to t25, t46, t71 to 75 from figure 5.7.

The variation of power procurement from term ahead is well noted in t26 and t73 to t93 from figure 5.6 .In the above case no effect of bilateral was seen because the nature of bilateral contract was such that it has a stringent prospect to take minimum power from every mentioned contract in the simulation model and it suggested that these bilateral contract are proven to be costlier in linear price calculation with assumed cost Rs/Mwh as per model calculation.

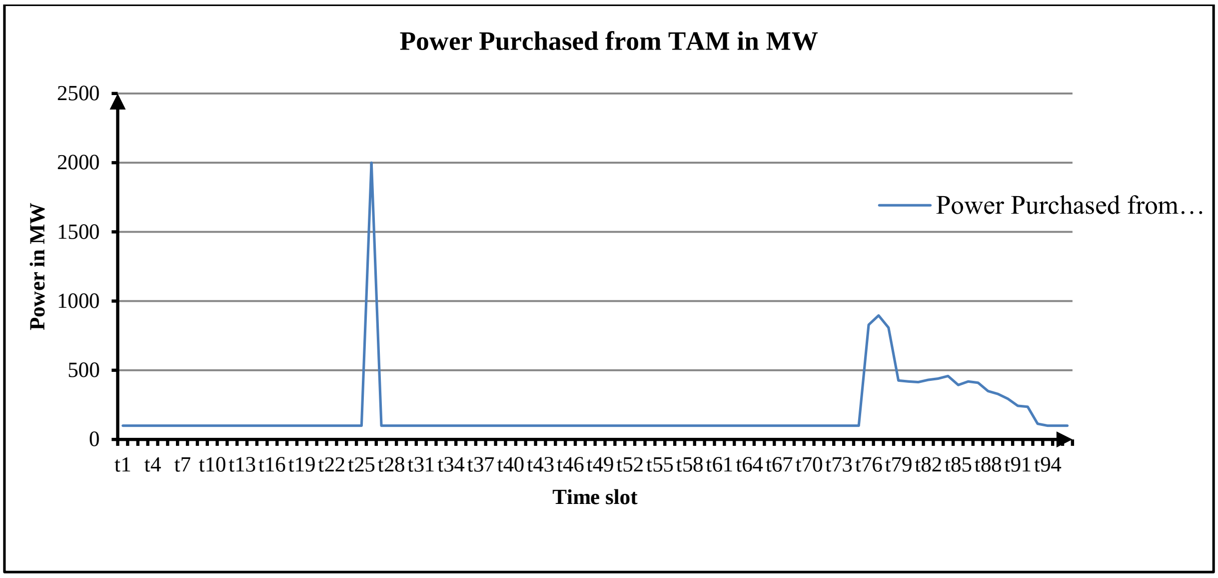

Figure 5-5 Power from Short Term Market TAM

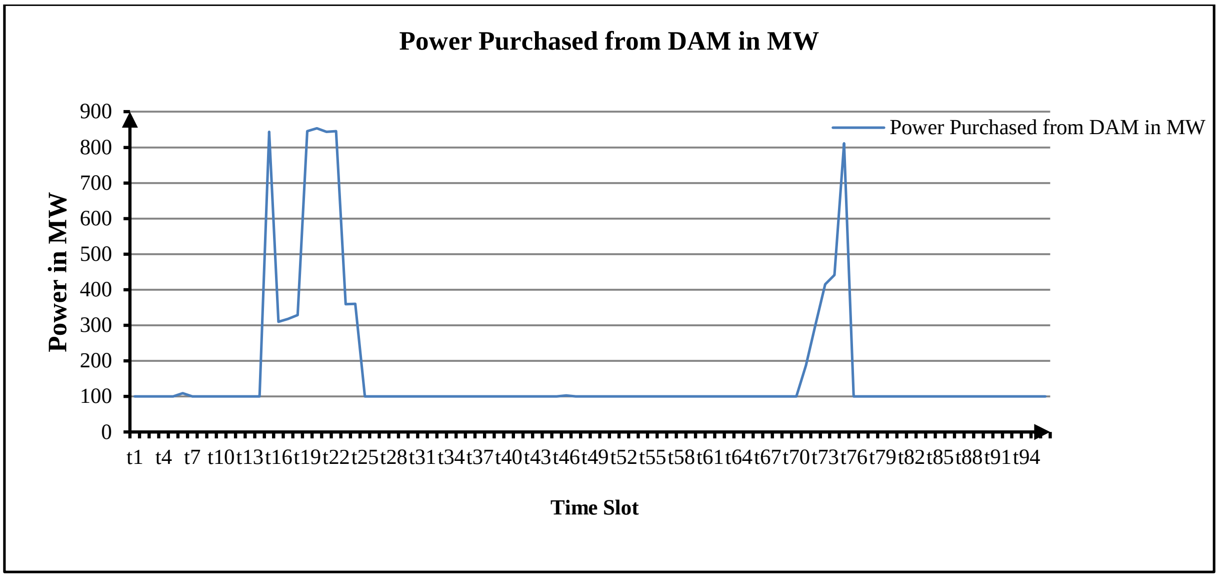

Figure 5-6 Power from Short Term Market DAM

Cost Analysis:

In this particular if the cost analysis is done then the cost of procurement from the state generator almost remain the same as in the previous case as shown in figure 5.1 with same number of generator participation.

Whereas, the cost from central ISGS decrease to a significant amount when compared to the pervious case where no participation of market was involved. But with the involvement of short term market the cheaper cost in every time slot is best opted from short term market option rather than the procurement from central or state generators.

From the table shown below the various structured cost is achieved after the model simulation

Table 1 Cost of 22nd Septemebr

Source of Procurement	Cost in Rupees
Central Generating Plant	2.7839e+8
State Generating Plant	5.8378e+7
Term Ahead Market	4.6833e+7
Day Ahead Market	4.2161e+7
Total	**4.2577e+8**

Case 2: Demand highest for the 20 July

In this scenario the temperature on 20 July 19 was around 45 degrees. It could lead the increase in demand in all the time slot of the day? For better understanding the effect of demand and cost of power procurement from various available sources can be best described in this particular case. The incremental effect of cost can be more in as the number of generator commitment can more in number to meet the sudden demand or the role of short term market can play significant role to achieve the demand in the best optimize way. As in the model for this particular scenario bilateral contract and it probable influence probability is also considered with constant cost in every time slot and on the generation side the renewable generation of that particular day is also considered.

Findings:

From the graph shown below the power from the state generation is almost constant with new generating unit added Gs20,Gs21 and Gs22 .This new addition of generating unit contribute in every time slot as it been cheaper in cost. Therefore the power purchased quantum is increased as the demand is increased similarly the participation of central plant also increased.

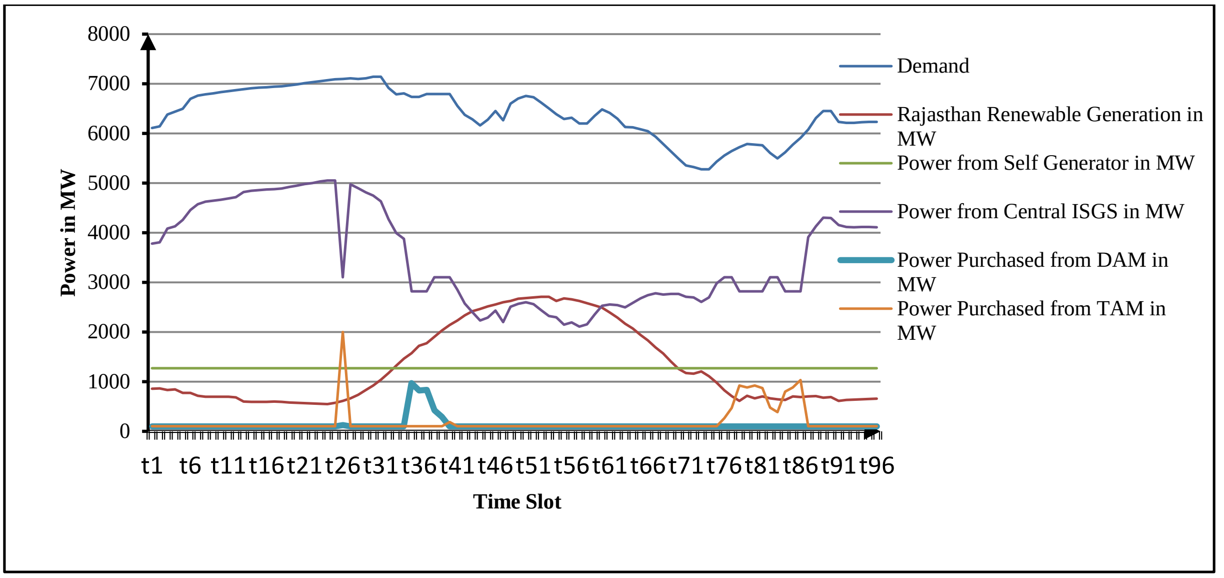

Figure 5-7 Power from Short Term Market DAM

The trend of graph is followed by the central generating plant in initial time slot of the day as in the starting period of official hour of the sudden demand is increased and the renewable energy generation is low then at that point of time the short term market fulfills the demand in efficient way.

During the day as the renewable generation increases the participation of the existing central generators are reduced with their prescribed ramp and ramp down as assumed in chapter-4. During day the graph of power from central ISGS nearly follow the same trend line as demand graph. Generally we can conclude that such plant can be used to meet the base load demand.The constant nature of procurement from state generating unit depicts the some part of base load is satisfied through it.

The peak during the day is fulfilled by the short term market in certain time slot t35 to t39 and t76 to t86 and for the rest of the slot it almost remained constant.

Here through this model simulation result it was found that the participation of the short term was active in the entire time block as it optimized the cheaper cost and the availability so such cheaper cost from the short term market.

In the above case no effect of bilateral was seen because the nature of bilateral contract was such that it has a stringent prospect to take minimum power from every mentioned contract in the simulation model and it suggested that these bilateral contract are proven to be costlier in linear price calculation with assumed cost Rs/Mwh as per model calculation.

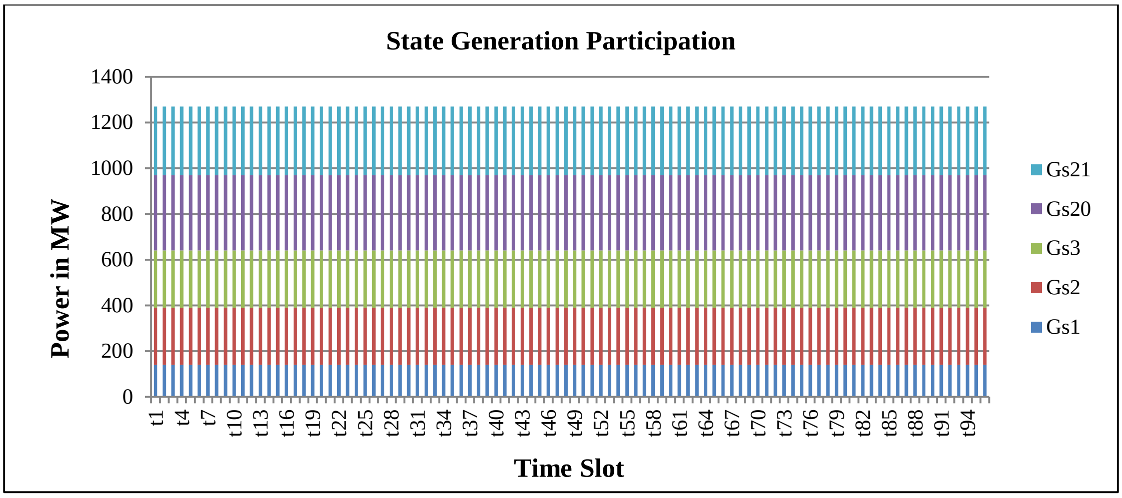

Figure 5-8 Power from Short Term Market DAM

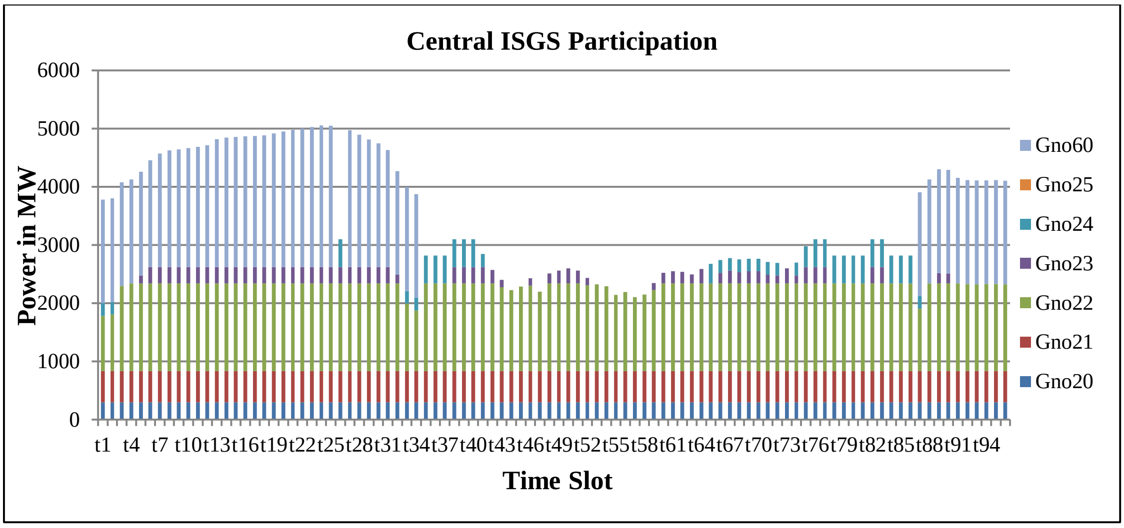

Figure 5-9 Power from Short Term Market DAM

Cost Analysis:

Table 2 Demand highest for the 20 July

Source of Procurement	**Cost in Rupees**
Central Generating Plant	4.1442e+8
State Generating Plant	9.85178e+7
Term Ahead Market	4.91283e+7
Day Ahead Market	5.0216e+7
Total	**6.1229e+8**

- To check the effectiveness of the model with the short term market.

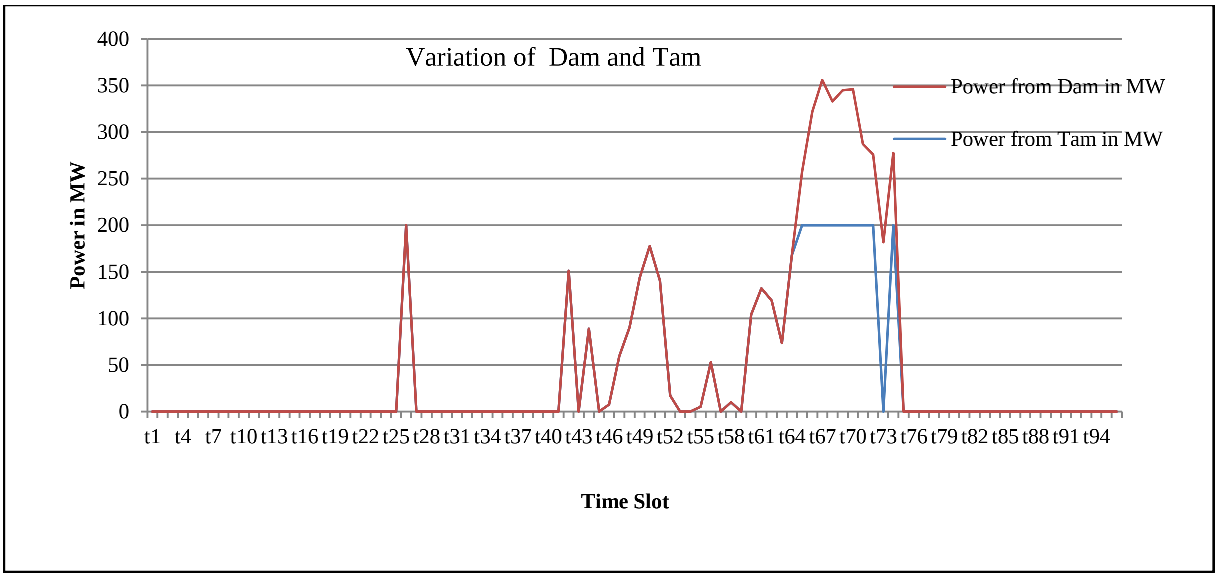

Figure 5-10Power from Short Term Market DAM

In this case the effectiveness of tam and dam are checked in the simulation model to study the best possible of market on the procurement planning.

In this case the same demand, renewable generation, dam price and tam price is assumed to be 3000rs per MWh and the rest are all the same input only the variation in lower limit is done power of tam and dam.

It is noted that now the procurement from market is not in every slot as it was in previous case where the model took the minimum power limit of the tam and dam in nearly many time slot.

This particularly is case which it can give the best possible knowledge of when and what quantum to be purchased from the short term market to meet the individual time slot demand hike. This participation of tam and dam is shown in time slot wise in figure 5.11 where we found that they have major contribution in the evening peak hours of the day. Which can be generally cross verified with the demand data of that particular day from utility.

In this particular case as noted from the figure 5.11 the dam and dam procurement are from the limited time slot and it reduces the overall cost of procurement from the previous described case in the preceding writing.

It is well noted that this procurement is supporting to meet the hike in demand the different time slot like t61 to t73 in the case of dam as shown in figure 5.11

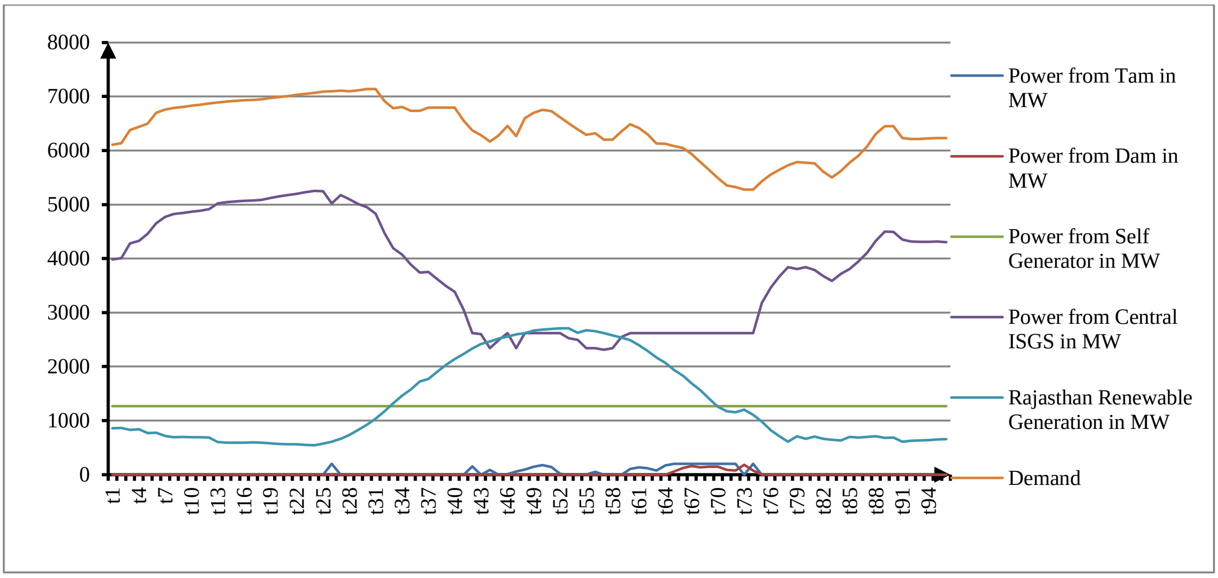

Figure 5-11 Power Procurement from Various Sources

In the above figure 5.12 the various types of procurement sources graph is reflected in every time slot.

The power procurement from the state generating plant almost remains constant as in previous case with same amount of power generation in every time slot.

From figure 5.12 it is noted that the smaller peak in time is fulfilled with support of market and this present case we note that participation of dam and dam in that particular time slot takes place in which the peak is incurred during the day.

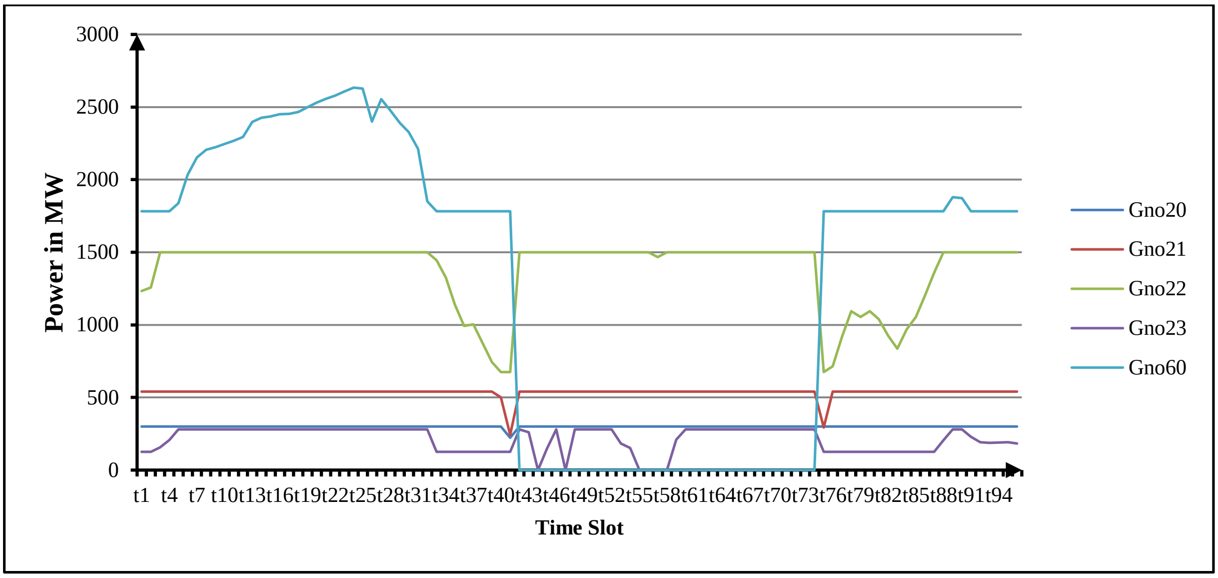

Figure 5-12 Power Procurement from Central ISGS

From the above figure 5.13 we can note that the participation of the all generator remains with increased power to be procured from all these particular generators the most probable cause of this was that the overall cost of those particular generator are cheaper as compared to the other generators.

Cost Analysis:

Table 3 Cost with no bilateral participation

Source of Procurement	**Cost in Rupees**
Central Generating Plant	4.4864E e+8
State Generating Plant	9.85178e+7
Term Ahead Market	1.0032 e+6
Day Ahead Market	3.8211Ee+6
Total	**5.6101E e+8**

Therefore from the cost analysis from the model in this case as shown in table 3 the overall cost is reduced to significant amount. The total percentage reduction in the total cost is 8.36% on a daily basis. There is no change in the cost of procurement from the state as it is same in the previous case. Cost of term a head and day ahead is reduced to 97.99% and 93.46%.whereas the price of procurement from central generating unit has increased by 7.628%.

With this case we conclude that with the projected demand of any particular day the limit should be kept minimum in the model in other words it means that we should or we are not bound to buy power from market with minimum certain limit .It is the choice of model formulation which would decide what minimum quantum of power to be purchased from the market. In the previous case the overall cost was higher if we bound to take power from the market as this can be a case when we know that the availability of other resources is not available due to technical issue or due to others reason too. This model suggested buying such cheaper power from the market rather than commitment of new generating unit or the existing generating unit with higher variable cost or higher total cost. When we know that the procurement from other source expect market can fall in deficit amount to meet the demand all throughout the day so in this scenario the first case is applicable to find the best possible procurement to be done from other remaining source with optimized cost.

In the above case no effect of bilateral was seen because the nature of bilateral contract was such that it has a stringent prospect to take minimum power from every mentioned contract in the simulation model and it suggested that these bilateral contract are proven to be costlier in linear price calculation with assumed cost Rs/Mwh as per model calculation.

- To check the effectiveness of the model with the bilateral contract.

In the figure 5.13 the effect of bilateral was seen because the variation of bilateral contract was such that it has a reflection and a noted participation with other input parameter to be same as in the above scenario discussed above .In the figure 5.14 shown below the variation of bilateral contract procurement strategy can be noted which revels its participation in pragmatic way.

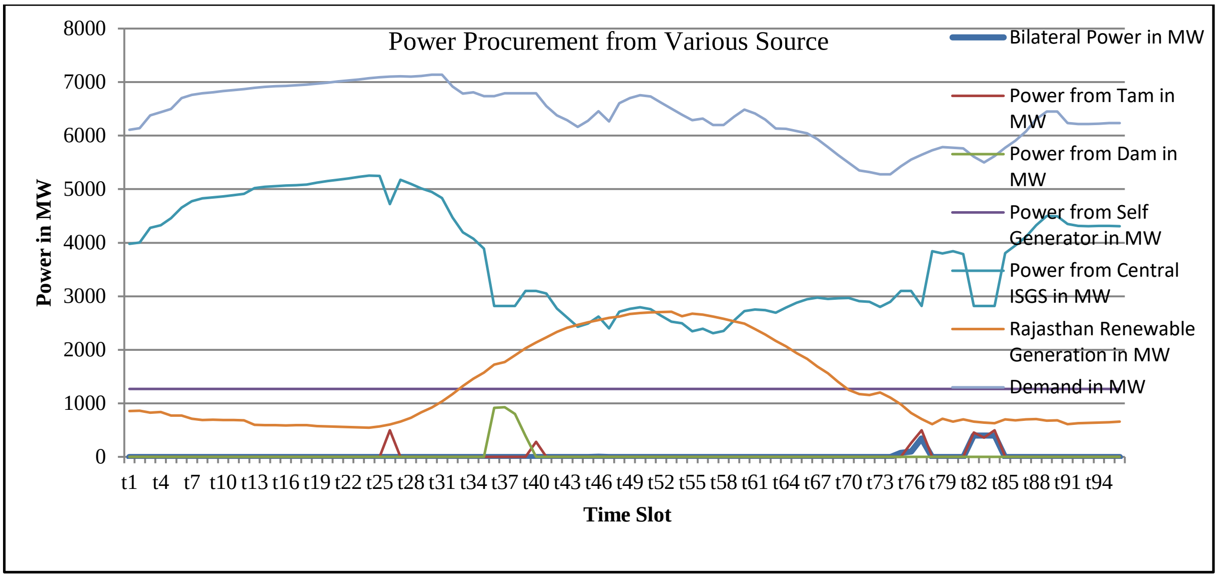

Figure 5-13 Power Procurement from central ISGS

This particularly is case which it can give the best possible knowledge of when and what quantum to be purchased from the short term market and the utilization of existing bilateral contract to meet the individual time slot demand hike. This participation of short term and bilateral contract is shown in time slot wise in figure 5.11 where we found that they have major contribution in the evening peak hours of the day. Which can be generally cross verified with the demand data of that particular day from utility.

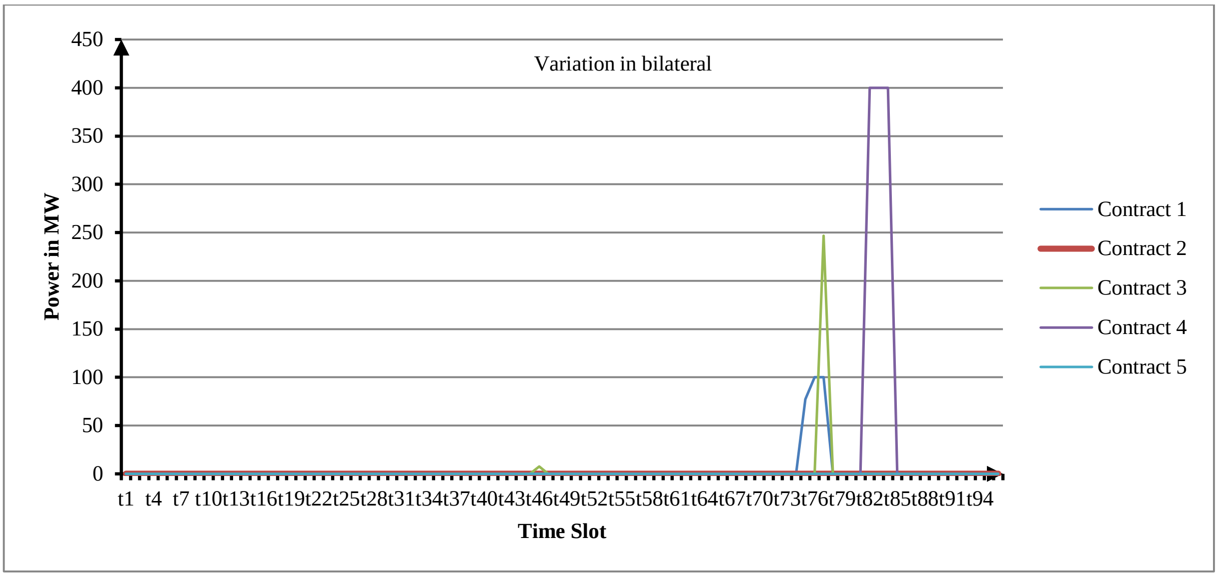

Figure 5-14 Power Procurement from Bilateral Contract

Cost Analysis:

Table 4 Cost with bilateral contract

Source of Procurement	**Cost in Rupees**
Central Generating Plant	4.4449 E e+8
State Generating Plant	9.85178e+7
Term Ahead Market	7.0841 e+6
Bilateral Contract	5.1952E+6
Day Ahead Market	8.7296 e+6
Total	5.6402**e+8**

Therefore from the cost analysis from the model in this case as shown in table 4 and table 5 the overall cost remains the same. With, no significant amount change in the procurement cost from state, central isgs and day ahead market. We can mark a change in term ahead market cost reduction in table 5 when compared to its cost in table 4.the cost of bilateral contract increases with its more prominent participation when the variation in the limit of such contracts are done.

In this study of particular we found that overall remains the same but it give the better insight to judge of what quantum to be procured from the term ahead market and how much to be procured from bilateral existing contract.

Table 5 Overall cost

Source of Procurement	**Cost in Rupees**
Central Generating Plant	4.4449 E e+8
State Generating Plant	9.85178e+7
Term Ahead Market	2318 e+6
Bilateral Contract	9.0474e+6
Day Ahead Market	8.7296 e+6
Total	5.6402**e+8**

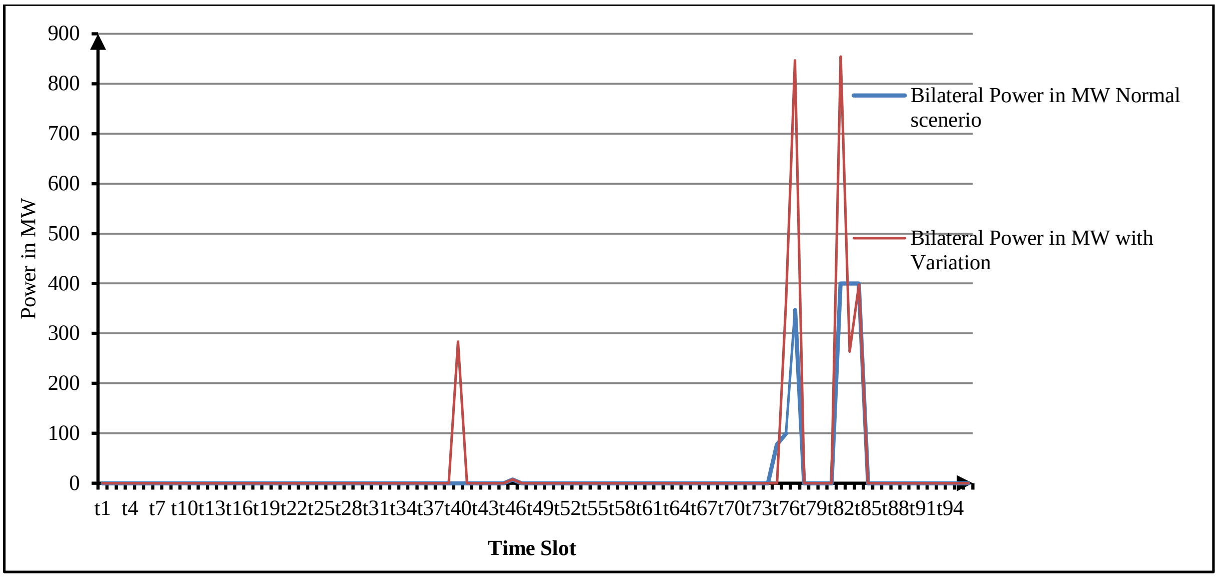

Figure 5-15 Power Procurement from Bilateral Contract Comparison

From the above figure 5.15 with variation bilateral contract parameters the participation of bilateral contract increase in terms of power procurement from such contracts and their reflection of cost as compared in table 4 and 5

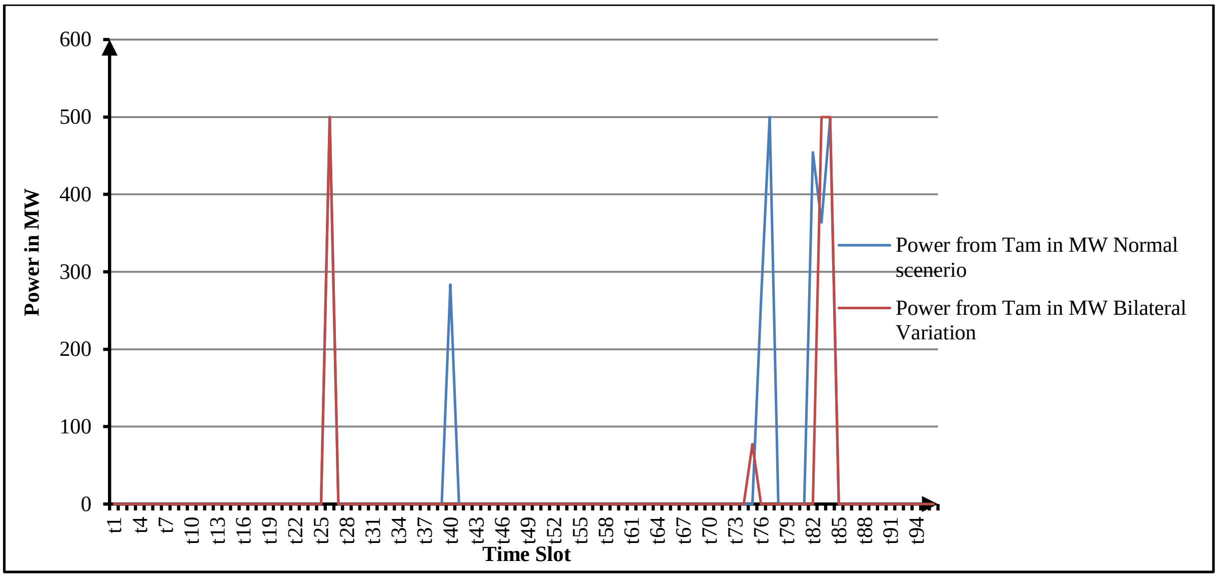

Figure 5-16 Power Procurement from Tam with Variation in Bilateral Contract

From the above figure 5.16 with variation bilateral contract parameters the participation of bilateral contract reflects it effect in term ahead market as noted such variation in it from figure 5.16 where the participation of term ahead market decreases in procurement of power from such segment.

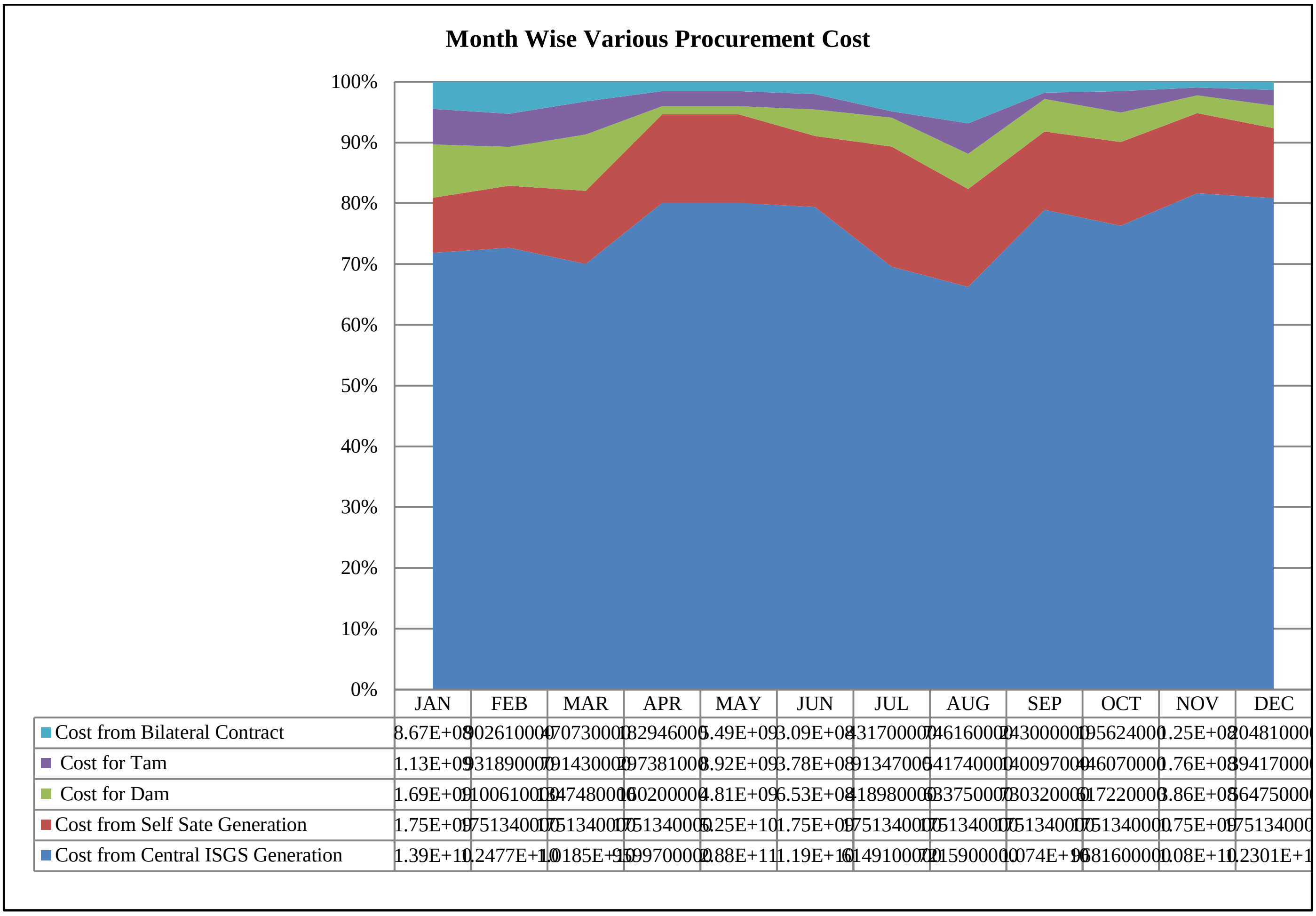

Figure 5-17 Power Procurement Cost Month Wise

From the above figure the month wise cost of various procurement is shown it very clearly depicts that as the projected demand increases the overall cost of procurement increases with more participation of short term. As per the result of model simulation it is to be noted that it also suggest for involvement of short term market to meet the sudden demand in certain months. The model result shows that state generation cost is almost constant with slight variation, whereas the major procurement cost change occurs in market and central ISGS as per the variation of demand.

The number of state and central generators cost are optimized in every case scenario to give their particular cost in conjecture to market cost also .The significant change occurred in the power procurement and cost from short term market which reveals that how the short term can play in the best efficient way to fulfillment of demand with optimized cost. From above figure the major percentage of total cost is governed by central ISGS plant followed by state generating plant.

This is found that the overall cost is highest for the month may as it has the highest forecasted demand due to linear variation relationship of procured power in short term and term ahead market their cost also increase as more cheaper power is procured from market rather than procuring higher variable cost power from state generation plant. There is no variation in the amount of power from state generation as compared to other months therefore the simulation result suggest that sate generation plant variable cost are higher and should not be procured after a certain level of power .

Power Procurement Month Wise for the State of Rajasthan

In the figure below the cost components of various short market segments are shown from this we can have a significant insight of short term market and its vital role in power procurement planning. For the state it further enumerates that procurement from these segment of short market are cheaper as per model simulation.

The major participation of such market are seen in the month of January, February, March as compared to other months of the year as the market price were cheaper or the same quantum of power procured from other available source like state generation and central isgs. The model enabled us to know what quantum to buy in which particular time of the day, paralleling the simultaneous procurement from state and central isgs with their respective quantum to be procured.

This model suggested buying such cheaper power from the market rather than commitment of new generating unit or the existing generating unit with higher variable cost or higher total cost. When we know that the procurement from other source expect market can fall in deficit amount to meet the demand all throughout the day so in this scenario the first case is applicable to find the best possible procurement to be done from other remaining source with optimized cost.

In the below graph the maximum cost contribution is from term ahead in comparison to other component of short term market. It reveals that day ahead procurement option can be one of the best option to meet the peak during a day.

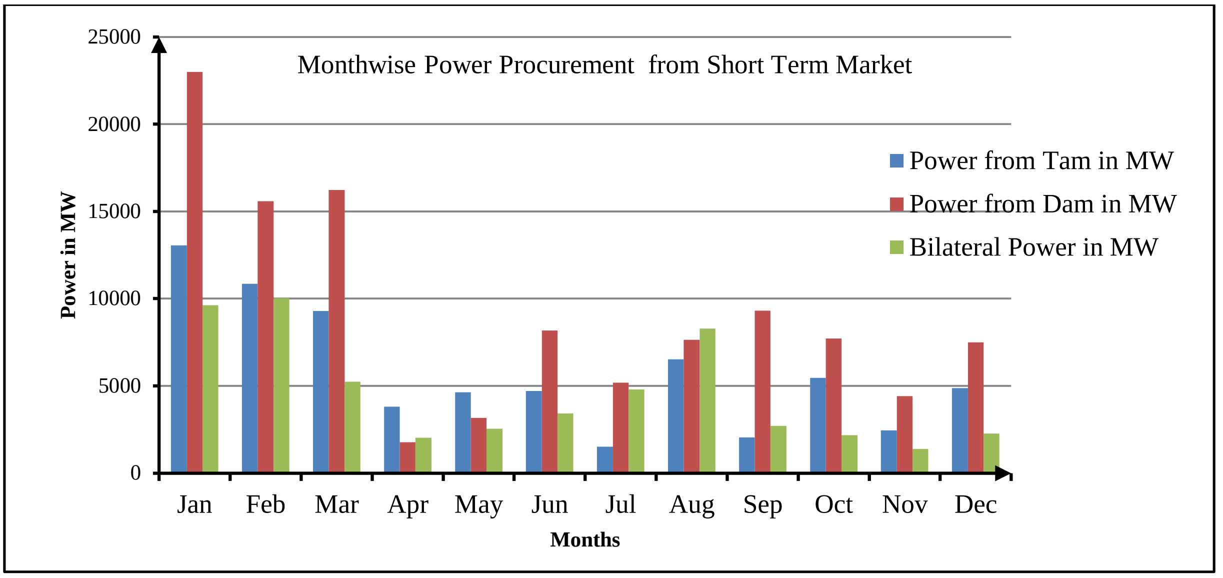

Figure 5-19 Month Wise Power Procurement from Short Term Market

In the graph shown below variation in procurement power from central isgs and state generation plants is shown there is a major variation in power procurement from central isgs is noted. The model suggested that sate generation is remained constant all throughout the year as it goes with the compliance of long term ppa signed with the state generation unit as the consumer continue to pay fixed cost but the variable cost component which get affected through the procurement is optimized and we get as state generation constant suggestion from model simulation.

Whereas as the variation in power procurement from central isgs is suggested by the simulation output such variation can be noted and can be handed well before in best optimized way .This model suggest the optimized procurement with perfect dynamical attribute how much to procure, when to procure and at what optimized cost all are answered perfectly.

While it was previously found in many pratical experience that some of the plants were not scheduledued upto the rated rating of their capacity and henceforth remains under utilized by their own condition and in the absence of a platform where this expensive capacity would be available to some consumers, the plants remain in partial use. The present scheduling mechanism adds a layer of non clarity with inefficient methodology in practice by the system and makes it difficult for the system operator to detect and send unused or fist priority utilization of low-cost generation. This gloomy optimism of self-organization and mal practice can be overcome through the current model with efficienct and effective outcome.

From Figures 5.19 shows how the top part of the demand is achieved by isgs generators as the mid-range manufacturers have a range of cost-effective switches. The existing practice in the state of Rajasthan provides a pre-date system (for generation under long-term contracts) that weakens the substantial in addition to financial purity of transactions, as both producers and exporters can review the 4- time block system before moving any economic debt. This makes system performance prone to many uncertainties and with this model of measurement such uncertainty is overcome

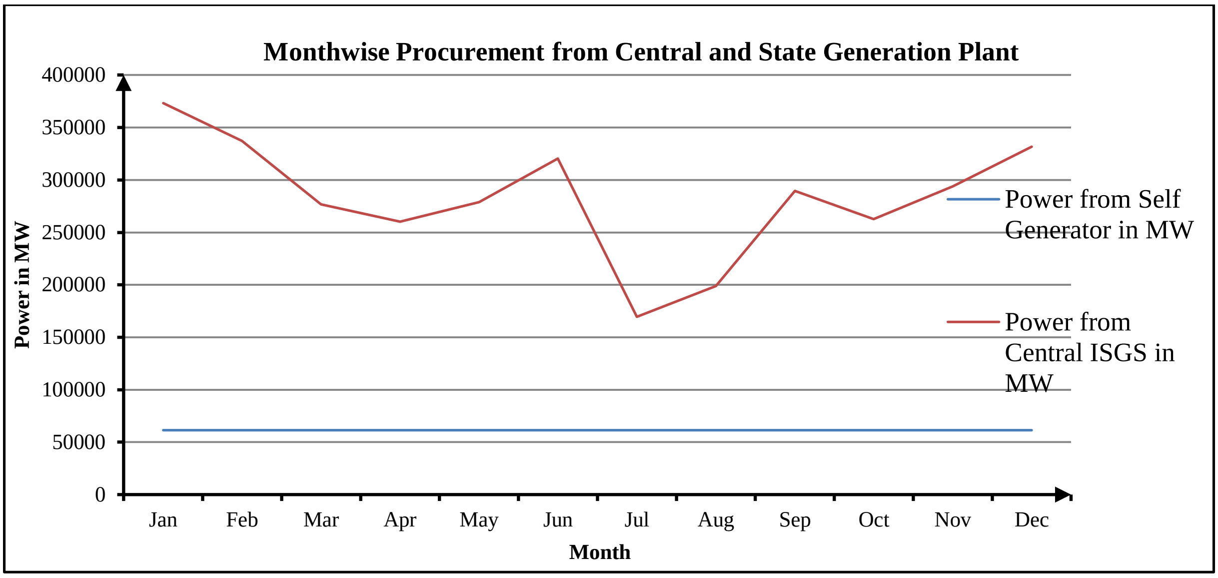

Figure 5-20 Month Wise Power Procurement from central ISGS and State

It is evident that with the need for the program we can be reached with the cheapest generation.Cheaper generators are widely used to reduce their URS (which does not require a surplus) overhead, while expensive manufacturers are downsized. The revised generation works best for the low-load generation without overload to congregate the demand. Therefore, the entire demand meets a much lower cost than the current shipping frame. Dispatch and cost-utility framework maximize the use of low-cost journals while minimizing and reverting to specific, cost-effective manufacturers. The overall cost of petrol is reduced as more and more producers are reduced.

Other challenges that arise from the practice of budgeting and planning for non-essential expenses include a deficient flexibility to cope with recurring variations in addition to fluctuations within demand. For case in point, a contracted discom with hydro producers was unable to use this power existing at this time of monsoon period. In some cases, in order to meet the peak value in the evening, discoms are strained to maintain low-cost energy storage during peak times and during low generation generation. As a case study has been much discussed in the application of the state of Rajasthan when considered closely with all relevant details of generation and demand. Poor procurement The centralized planning does not allow for the efficient use of cheap reproductive power due to the lack of transparency in some discoms. Availability of unwanted resources (URS) from low-cost generating stations also means that it has the potential to make planning and shipping possible to reduce the cost of discom power purchases.

Chapter-6 Conclusion

The present work is done in two different major segregation. The first phase involves the collection of data for use and development of calculations using Microsoft Excel as the current cost calculation is used. While the primary phase deals with the development of the energy procurement framework. In fact, the concept of the energy procurement framework is based on the findings of the stochastic LP model. The procurement strageiges has a valued supply chain which provides four major segmented sources from where the purchase can be done. The distribution function must come up with appropriate energy acquisition strategies to congregate the needs of the end customers at low price.

The Linear Programming model formulated for this present work has led us with a systematic acquisition process. The plan has clearly outlined the amount of energy that will be available to future and future PPAs, the two-country contract options, which ultimately increase the price of electricity procurement. Presently, the service is under obligation to purchase at least a certain amount of power from suppliers under long PPAs, even though the cost of other suppliers' energy is very high. However, the utility model suggests that the utility should try to gain power only from a selected set of providers. Studies have conducted sensitivity studies on various parameters including demand, energy costs under long-term PPAs, energy availability under pre-purchase, etc.

Finally, the results of the sentiment analysis encouraged us to develop a framework for purchasing power keeping in notice the important factor like the cost of energy supply and uncertainty in energy supply. This model framework can be applied to other state utility as the the major base segment of procurement and other practice are same across the India.

This research work has been simplified to think in terms of capturing fluctuations in the cost of purchasing power. Future work can be done along with the present work where can address the unsechudeled interchange and its effectiveness in various scenario along with the selling segmentation power for the state of Rajasthan as in future the generation may get scaled at faster rate.

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