Asian Journal of Water, Environment and Pollution, Vol. 17, No. 2 (2020), pp. 49–54.
DOI 10.3233/AJW200020

Solar Power Trading Models for Restructured Electricity Market in India

Neeraj Kumar* and M.M. Tripathi
Electrical Engineering Department, Delhi Technological University, Delhi – 110042, India
✉ neerto100@gmail.com

Received December 31, 2019; revised and accepted January 8, 2020

Abstract: Solar PV is an emerging power source of modern times and its capacity is growing day by day. The increasing penetration of solar PV into grid makes it necessary to develop the electricity trading models and mechanisms for operation of evolving electricity market. This paper proposes some new power trading models for the Indian electricity market having good share of solar PV power which possibly may result in quality power, better demand management and competitive price. The highlights of the proposed models along with their limitations and challenges ahead are also outlined. The various proposed models may be applied in different states based upon their suitability.

Key words: Independent solar power producers, rooftop solar power, independent solar power, aggregator, solar power trading model, state solar power pool, distribution generators.

Introduction

Solar power is one of the effective power sources among wind, biomass and other renewable energy sources due to its high availability in India, about 5000 trillion KWh per year incident on the land (MNRE, 2018). By proper harnessing the solar energy, accelerating demand of energy 1137 billion KWh and per capita average of this is 841KWh (World Data, 2018) can be met and energy security can be achieved in a sustainable manner. Different models for electricity trading in restructured market were presented (Tripathi et al., 2016) for conventional sources of energy. With the addition of solar PV generation in the grid, distribution system becomes active and it works as an active distribution network (ADN). Due to large addition in the capacity of solar power the system will be benefitted in following ways:

- Power will be locally supplied to consumer and hence the burden on the main grid will be reduced; consequently transmission lines also relieved so that transmission losses will be also reduced.
- Transmission and distribution losses will be reduced. In India, average 23% of the total electricity generated is lost in transmission and distribution. In some of the states the loss in transmission and distribution is around 50% (Qureshi and Mahmood, 2009).
- Feeder capacity will increase and transmission cost will be reduced.

In India, the solar power generation plants are categorized in terms of generation capacity as small solar power plant (up to 99 MW), medium solar power plant (100 MW to 400 MW) and large solar power plant (more than 500 MW). Only large solar power plant needs transmission lines to transmit power to grid and in case of small and medium power plants they can directly be connected to the distribution lines for supplying power to the utilities. In the case of medium and small power plants, state distribution unit (SDU)

*Corresponding Author

needs to strengthen its capacity of distribution. Special distribution lines need to be installed to accommodate the additional solar power. The availability of large number of distributed generation of solar power may result in better competition and price of electricity may reduce.

However, to be able to use the solar power connected across the grid, a proper market mechanism and trading model for solar power trading required to be put in place. In this paper different solar power trading models and mechanisms are presented for state level solar energy market which can be suitably adopted by different states for incorporation of solar power as regular mode of power supply. The advantages of various models and expected challenges are also outlined.

Rest of the paper is organized as follows. In the second part of the paper, functions of components of solar power electricity market are presented. In third section different models for solar power trading is presented with their operating mechanism. In fourth section challenges in implementation of proposed models is discussed. And in fifth section paper is concluded with main findings.

Components of Solar Power Electricity Market

Different components and flow of power and money of proposed solar power trading is represented through Figure 1.

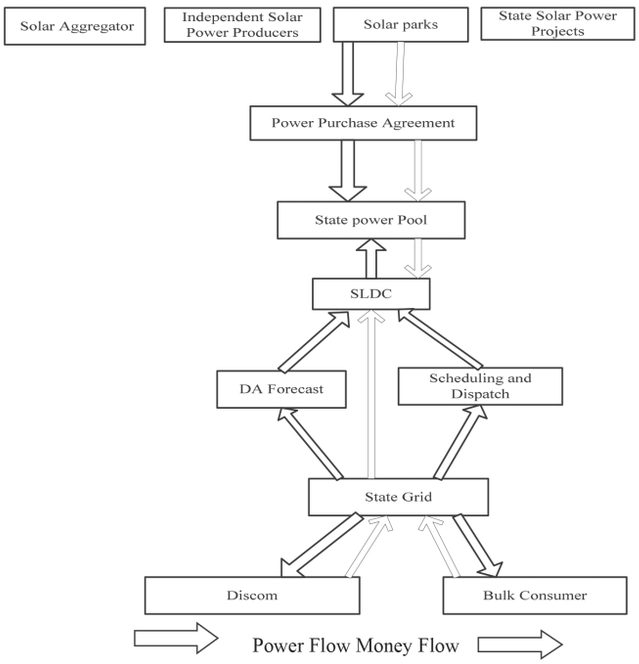

Figure 1: Operating mechanism for solar power trading.

(a) State Electricity Regulatory Commission (SERC) was established under Electricity Regulatory Commission Act in 1998 with the objective of rationalised electricity tariff, transparent trading mechanism and promotion of renewable energy for sustainable development and energy security. There are total 27 SERC established in India (SERC, 2019). Many SERCs are promoting renewable energy for meeting the demand; some of them are GERC, MERC, RERC and APERC. These states are giant in renewable power generation and generating large amount of power from solar and wind. With the view of availability of large capacity of solar power producers, individual solar power trading model is proposed working under same SERC.

(b) State Load Dispatch Centre (SLDC) to promote the solar energy at state level: A solar state load dispatch centre may be proposed for promoting the environment friendly benign energy sources. In this proposed centre all solar power producers including government solar projects (Solar parks, solar rooftop, solar society grid) and independent solar power producers are permitted to participate in power trading. An independent body has to set up for proper controlling and investigation of different processes involved related to generation trading, transmission of power and distribution. This independent or integrated body is named as solar state load dispatch centre (SSLC).

The role and responsibility of this SSLC are as following (SLDC, 2019)

(i) to supply reliable and quality power to consumer
(ii) supply electricity at competitive cost
(iii) proper monitoring over dispatch schedule
(iv) ensure transmission line maintenance
(v) advanced forecasting of power generation

(a) State Transmission Utilities (STU)
STU is responsible for maintenance of power transmission in state. For proposed solar power load dispatch centre requirement of new transmission capacity, lines are required to transmit power in urban, rural or may be longer distance is required, because objective of this SSLDC is to make electricity independent nation for that purpose we may transmit power in electricity deficit area through new tie lines. The purpose can be solved either by opting the private transmission line or by extending the existing transmission line capacity through proper channel.

(b) Power Pool Controller (PPC)
PPC is the controlling entity of power pool at state level. This provides a platform for power producers to sell their power capacity through a proper trading mechanism. Each power producer will participate in power pool for selling power through Power Purchase Agreement (PPA) (SPPA, 2019). Government has set up flexible rule for power producers to entering into power pool for selling power.

(c) State Distribution Utilities (SDU)
SDU is responsible for effective power distribution in state. Currently retailers have also come into the play for distribution of power. Retailers can purchase power directly from the power producers and it can distribute power to the bulk consumer or any specific consumer. For solar power distribution in state for proposed models, competition among the retailers is primarily required to provide quality power at competitive cost. In this restructured model consumers have choice for their power supply.

(d) Scheduling Coordinator (SC)
SC is responsible for demand and supply balance without the interference of power exchange. It manages the bid and supplier.

(e) Power Purchase Agreement
It is possible now setting up power plant without the PPA and it can feed power to the grid. But by signing PPA, it can reduce the risk of upfront of electricity price. It also helps to achieve sustainability in volatile energy market.

(f) Storage Unit
Due to intermittent nature of solar radiation, this unit is important to maintain the reliability of the supply system. Without storage unit solar power generation cannot provide all the characteristics of stable grid. The main objectives of this unit are as follow (EEST, 2018):

- Effective connection to gird – Solar power output highly rely on the weather conditions, output is not predictable exactly due to weather parameter uncertainty. Electrical Energy Storage Devices (EESD) can be used to mitigate or absorb these fluctuations.
- Standby power supply – It is required to compensate the unplanned outages of transmission lines, congestion management, due to exercise of power market etc.
- Shifting of power – When output power from solar is high and if this power is not utilised at particular time, this valuable power can be effectively stored in ESSD and can be traded when the price of power is high, usually it happens when the demand is high.

Solar Power Trading Models

There are four models for trading of electricity globally (SPPA, 2019)

- Monopoly model
- Single buyer model
- Open access model
- Power pool or wholesale market model

Solar Power Trading with Aggregator Model

In this type of proposed power trading model (Figure 2), different sources of power generation from solar can participate in trading and they can inject their power capacity in state power pool. According to the capacity, they are supposed to supply to serve different purposes. Like power generated from solar parks are generally higher in capacity; it can be used to serve peak load demand and accordingly they can bid with respect to power volume. Additionally aggregator model is introduced to strengthen the capacity and competition among solar power producers. Aggregators are important aspect of this model as it collects unutilized power from different houses of the society and individual house. As these individuals' house and houses under society are connected to the main society grid, unutilized power can be fed to the grid and effective power by the end of the day is substantial for trading. Figure 3 depicts the concept of aggregator. The concept of virtual power

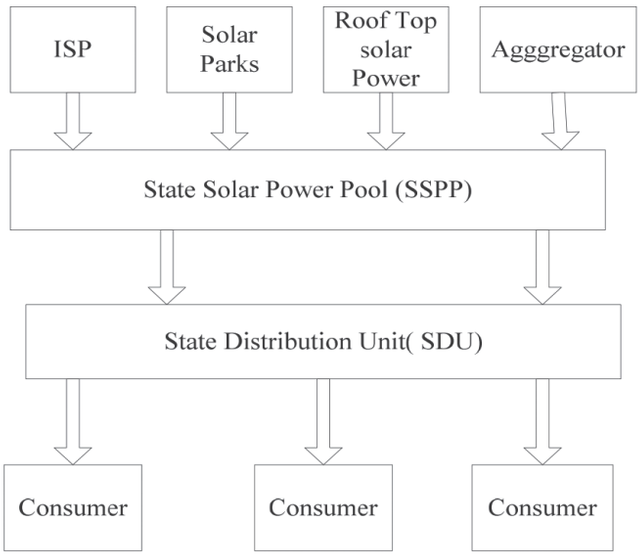

Figure 2: State power pool model for solar power trading.

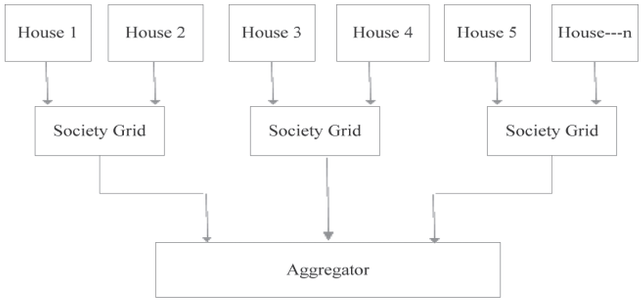

Figure 3: Aggregator model for solar power trading.

plant for market integration of DGs is presented (EEST, 2018). The main barrier in implementation of this model is to provide incentive in lieu of unutilized energy supplied to the grid.

Power Trading Model for Rural Area Supply

This proposed model (Figure 4) is based on energy sharing concept dedicated for rural area supply where all solar society grid (SSG) can feed unutilized power to aggregator and aggregator can supply this power capacity to rural area for agriculture and domestic purposes (Pentayya et al., 2012; Koraki et al., 2018). In modern day, society houses equipped with grid interconnected solar system which can feed unutilized power to the grid, they can get subsidy for that (ETP, 2016; Comodi et al., 2015). House owner is also contributing their surplus power for betterment of rural area and they are also power traders. Establishing proper transmission system for transmitting power to longer distance is one of the major task for the proposed model.

Solar Power Trading Model for Generation Side Competition Model

Numbers of solar power producers in country are increasing with greater pace and so the competition among generators. Independent solar power producers (ISP) and government solar projects like solar parks, solar roof top power etc. can participate in power pool to sell the power. After selecting the appropriate bid, which match the demand and supply ISO will finalize the deal. After that transmission of power can be allocated to the state transmission unit or if the transmission capacity is not sufficient the state can opt for private or licensed transmission network. This model is restructured version of solar power trading model and presented in Figure 5. In proposed model consumers/bulk consumer can buy power directly from solar power producers and negotiate the price directly from seller. As presented in Figure 4, due to larger capacity available in solar parks, bulk consumer can directly communicate with them for power purchasing. Rooftop solar power less than 5 kw capacity can participate in pool for power trading according to state solar policy (Fleischhacker et al., 2019; MNRE, 2019). Success of this proposed model depends on the number of solar power producers available to participate in power pool.

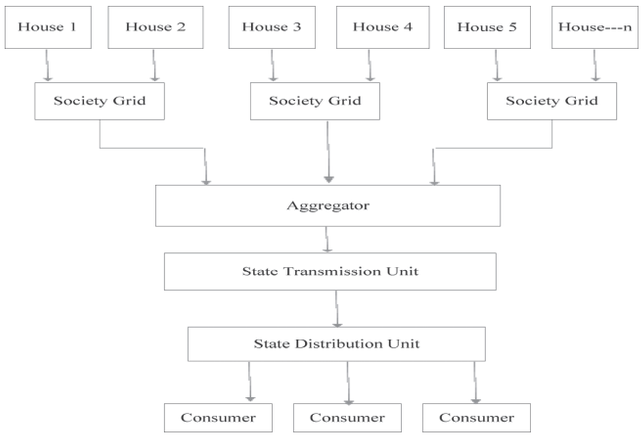

Figure 4: Solar power trading model for rural area.

Solar Power Trading Model for Retailer Fixed Model

In this model power producers are free to sell the power directly to power Distribution Company or retailer for their own profit without entering into pool. This model (Figure 6) does not restrict power producers to sell power only to state power pool but the Discom is bound to sell power only to the consumer through power distribution unit of state. In this model power producer have option to negotiate the price with retailer and Discoms or PDU for their own profit. This model helps the solar power generation potentially competitive. Facility of direct power purchase from the available generators is not available in this model.

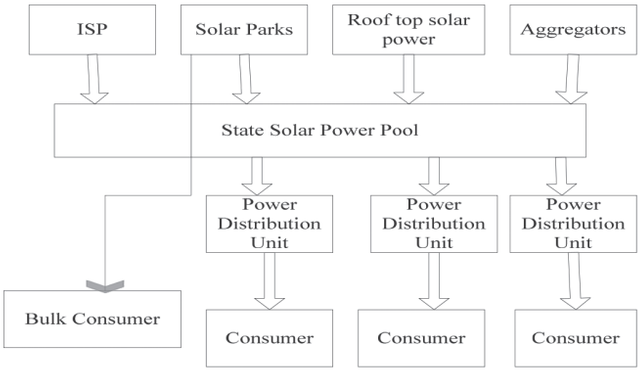

Figure 5: Solar power trading model.

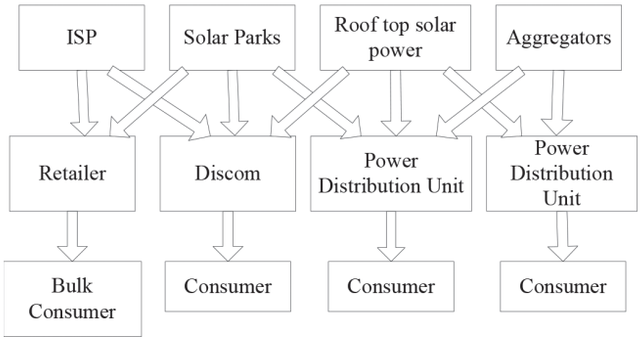

Figure 6: Solar power trading model for retailer fixed model.

Solar Power Trading for Retailer Flexible Model

It is evident from experience that effect of restructuring is lesser reported in distribution side, as most of the financial resources are aligned towards the generation side whether it is conventional or non-conventional generation. In distribution side the proposed model is to create competition at distribution end so that electricity can be transmitted to consumer at reduced cost. From retailer, consumer can buy power instead of SDU or private distributor whichever is supplying quality and reliable power at lower cost. Power trading must be done through proper wire network. Most of the things is common in this model (Figure 7) except potential competition at distribution end by introducing local power distributor or private distributor. These distributors can buy power from power pool or directly from power producers through integrated tie line and may participate in distribution.

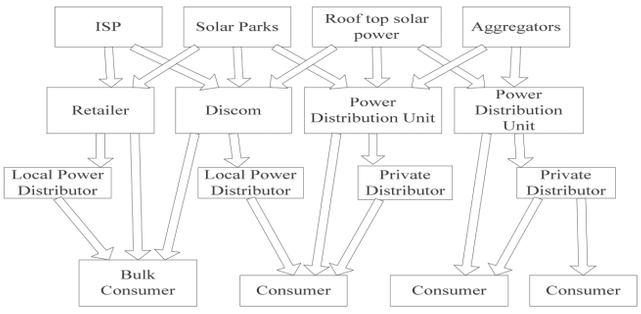

Figure 7: Solar power trading for retailer flexible model.

Challenges

The main barrier in implementation of this market model is lack of additional facility of transmission capacity. Additionally distribution sector in India is not ready to take up challenge of variability in supply and demand.

- Renewable energy sources based distributed generation require reactive power and almost 80% of the electrical load are reactive in nature, as load increases demand of reactive power increases. Reactive power imbalance is one of the major issues in such type of system.
- In addition to above problem RES based generation requires reactive power, and demand of reactive power increased from both generation and demand side will reduce the voltage profile of network.
- Solar power is fluctuating in nature. In order to compensate the fluctuating nature compensation devices are required for that purpose. D-FACTS devices need to install which will add extra cost to the solar distribution system. However the cost of D-FACTS is lower as compared to FACTS devices.
- Optimal location of PV sizing according to the demand will be a tough task for the designer.
- Price volatility due to intermittent nature of solar.

Conclusion

Solar is the promising and emerging source of energy and due to its rapid growth across the globe, it is part of future power. For promoting solar power generation at larger scale, a liberal and non-discriminatory market framework should be provided for trading of solar power. This will provide a new platform for solar power producers to come up with new innovation and efficient technologies in this field; additionally reliance on fossil fuel will be reduced. There are total five different models proposed for trading of solar power in Indian market context. Different models are to create healthy competition at generation and distribution side to make solar power available to everyone. These models are similar to conventional electricity market with minor changes in accordance with solar energy characteristics and nature of power such as storage unit is added to maintain reliability in supply system. Aggregator model is introduced to supply power in rural area for agriculture and domestic purpose. In this model surplus power from different houses are being fed back to the grid and it can be aggregated and be transmitted through tie line to the remote locations for powering the villages. In this proposed model society or house equipped with solar grid interconnected system can contribute to lighting up the rural area or they are power participating in power trading from home itself. These proposed market models for solar power trading need to be implemented at small scale at initial stage and then can be extended at state level.

References

Comodi, G. et al. (2015). Multi-apartment residential microgrid with electrical and thermal storage devices: Experimental analysis and simulation of energy management strategies. *Appl. Energy*, **137:** 854-866.

EEST (2018). Technical Overview of Electrical Energy Storage Technologies. Accessed March 20, 2019 https://www.iec.ch/whitepaper/pdf/iecWP-energystorage-LR-en.pdf.

Energy Technology Perspectives (2016). Towards Sustainable Urban Energy Systems, Paris, France.

Fleischhacker, A., Auer, H., Lettner, G. and A. Botterud (2019). Sharing Solar PV and Energy Storage in Apartment Buildings: Resource Allocation and Pricing. *IEEE Transactions on Smart Grid*, **10(4):** 3963-3973.

Koraki. D. and K. Strunz (2018). Wind and Solar Power Integration in Electricity Markets and Distribution Networks through Service-centric Virtual Power Plants. *IEEE Power & Energy Society General Meeting (PESGM)*, Portland, OR, 2018.

Ministry of New and Renewable Energy (2018). Programmes and technology. Accessed July 20, 2018 https://mnre.gov.in/solar

Ministry of New and Renewable Energy (2019). Grid connected solar power Rooftop – State Policies and SERC Regulatory/Tariff Order. Accessed September 16, 2019 https://mnre.gov.in/grid-connected-solar-rooftop-states-policies-and-sercs-regulatory-tariff-order

Pentayya, P., Mukhopadhyay, P., Chakraborty, G. and N. Ahmad (2012). A perspective of power market development in India – Market Design and operation.

Qureshi, S.A. and F. Mahmood (2009). Evaluation by Implementation of Distribution System Planning for Energy Loss Reduction. *Pak. J. Engg. & Appl. Sci.*, **4:** 43-55.

Solar Power Purchase Agreement (2019). Accessed March 20, 2019. www.seia.org/

State Electricity Regulatory Commissions (2019). Accessed January 20, 2019 http://www.cercind.gov.in/serc.html

State Load Dispatch Centre, Delhi (2019). Accessed February 25, 2019. http://www.delhisldc.org/

Tripathi, M.M., Pandey, A. K. and D. Chandra (2016). Power system restructuring models in the Indian context. *The Elecricity Journal*, **29:** 22-27. doi: 10.1016/j.tej.2016.05.002.

World Data (2018). Energy Consumption in India. Accessed August 28, 2018. https://www.worlddata.info/asia/india/energy-consumption.php