Solva
Evaluate the value of distributed solar and storage

AurovilleConsulting

Maximising the benefits of distributed solar energy: An evaluation

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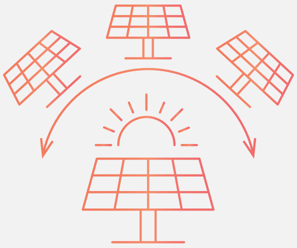
Purpose

To evaluate the network and societal benefits of introducing distributed solar energy at Karungalpalayam HT Feeder in Erode district, Tamil Nadu, using the Solva tool developed by Auroville Consulting.

Key messages

- Using Solva tool, the size and location for integrating distributed solar energy on the Karungalpalayam HT Feeder was successfully identified.
- Using Solva tool we have identified that when a 4.50 MW solar energy system is introduced on the Karungalpalayam HT Feeder it offers a total benefit of INR 12.84 per kWh. These benefits are subdivided into network benefit and societal benefit.
- The societal benefits achieved from the integration contributes to 8.84 INR/kWh or 69% of the total benefit. Network benefits are found to be at 4.00 INR/kWh or 31%.
- In Karungalpalayam HT feeder with the integration of distributed solar energy, the distribution line losses show a reduction, particularly if interconnected at the middle end or tail end of the HT feeder.
- When solar energy system is interconnected at the tail end or at the middle end of Karungalpalayam HT Feeder, a deferral of feeder upgradation is found.
- In particular to Karungalpalayam HT feeder, interconnecting the distributed solar energy system close to the point of consumption offers the highest benefits.



Auroville Consulting

Using our expertise in ecological and socially responsible development, we work for a prosperous eco-system that supports all life on this planet. Our approach is multi-faceted: We collaborate with academic, private and public sector partners both in India and Internationally, helping to develop sustainable urban and industrial development policies, ecologically friendly technologies – and the minds of future leaders. Founded in 2010, Auroville Consulting is a unit of the non-profit organization Auroville Foundation.

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Sustainable Energy Transformation Tamil Nadu (SET)

SET aims to facilitate higher clean energy deployment in the State by working with stakeholders in order to find sustainable and equitable solutions. SET is a collaborative initiative by Auroville Consulting (AVC), Citizen Consumer and civic Action Group (CAG), the World Resources Institute India (WRI).

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Background

In 2022, The Tamil Nadu government set a target to add 20 GW of solar energy capacity and 10 GW of battery energy storage capacity by 2030. This capacity addition is expected to be carried out in every district using distributed generation systems (DT Next 2021). The state has also put in place policy and regulatory frame works - the Tamil Nadu Solar Policy 2019 (TEDA 2019) and the Generic Tariff Order for Grid Interactive PV Solar Energy Generating Systems (GISS) 2021 (TNERC 2021) - to propagate the adoption of grid connected distributed solar energy.

According to Central Electricity Authority (CEA), distributed generation resource is defined as generation station feeding electricity into the electricity system at voltage level of below 33kV (CEA 2019).

As the adoption of distributed generation system increases, smart grid-integration of these becomes exceedingly important. Studies that provide an avoided cost assessment offer an opportunity to network operators to identify the most appropriate distribution network nodes and distributed renewable energy (DRE) capacities.

In a previous study (Auroville Consulting 2020), the techno-commercial viability of introducing distributed solar energy on high tension feeders under the Erode substation were analysed. The analysis considered three different solar energy penetration scenarios.

The technical impact analysis included parameters such as voltage, reactive power, feeder current capacity, and distribution losses. Impact on Cost of Supply (CoS) and net revenue were considered for the financial analysis. It was concluded that the introduction of distributed solar energy could lead to voltage improvements, decreased distribution losses and a reduction on the CoS. One of the recommendation of the study is to conduct a feeder-wise solar energy hosting study to determine the optimal energy capacity.

Other methodologies to assess the value of distributed energy resources have been introduced by CEEW (CEEW 2019) and NREL (NREL 2021). As compared to the CEEW study, the NREL methodology includes the environmental and health benefits to determine the value of grid connected distributed solar energy.

In this study, we evaluate the network and societal benefits of introducing distributed solar energy on Karungalpalayam HT Feeder under Erode substation in Tamil Nadu. Solva tool is used for this analysis. Solva is an open source python based tool for simulating and analysing the avoided network and societal costs by interconnecting DRE at the distribution network level.

Karungalpalayam HT Feeder

The Karungalpalayam HT Feeder has a voltage of 22 kV and spans over a distance of 18.96 km. Table 1 displays other details of the feeder.

Table 1: Details of the Karungalpalayam HT Feeder

Feeder	HT Karungalpalayam
Feeder type	Overhead
Feeder voltage (kV)	22.00
Feeder length (km)	18.96

Source: Auroville Consulting 2020

Karungalpalayam HT feeder caters to primarily domestic connections (61%) and the remaining connections are shared among other categories as shown in table 2.

Table 2: Consumer profile of Karungalpalayam HT Feeder

Consumer	Load (kW)	% share
Domestic	27,448	61.34
Commercial	8,754	19.56
Industrial	6,636	14.83
Others	1,903	4.27
Total	44,741	100.00

Source: Auroville Consulting 2020

Methodology

Solva tool can be used to carry out a power flow analysis for the distribution network. The power flow analysis provides insights on active power and voltage distribution.

The Value of Distributed Energy Resource (VODER) is divided as network benefits (INR/kWh) and societal benefits (INR/kWh). The network benefits include:

(i) Avoided cost of energy (ACE)

(ii) Avoided distribution capacity cost (ADCC)

(iii) Avoided transmission capacity costs (ATCC)

(iv) Avoided generation capacity cost (AGCC)

Concurrently, the societal benefits take in consideration:

(i) Avoided CO2 emission costs

(ii) Avoided SO2 emission costs

(iii) Avoided NO2 emission costs

(iv) Avoided PM2.5 emission costs

Network and societal benefits are discounted over the analysis period. The environmental values for pollutants were considered to replace coal as fuel. For a detailed methodology description refer to the Solva Methodology document (Auroville Consulting 2022a).

Selection of DER system size

To determine the system sizes, we have limited the selection to satisfy two criteria :

(i) System size must be below the maximum load carrying capacity of the feeder

(ii) System size shall not result in surplus solar energy that flows beyond the selected HT feeder.

For the selected feeder, it was observed that 4.50 MW solar energy system satisfies both criteria. Hence, 4.50

MW is the maximum system size considered. Other sizes considered are 3.00 MW and 2.00 MW (refer to table 3).

Table 3: System sizes selected for the analysis

% share of load carry capacity	Solar System size (MW)
100 %	4.50
70 %	3.00
40 %	2.00

Base case description

In the base case scenario, the three system sizes are simulated at feeder analysis level and as a solar only case using the Solva tool (Auroville Consulting 2022b). Solva tool offers three points of interconnection – (i) sending end, (ii) middle end and (iii) tail end – for the introduction of distributed solar energy at the distribution network. For the base case scenario, we consider the interconnection point of the distributed solar energy to be at the tail end.

In this analysis we have considered the 2020 net (solar plus wind) state load profile for Tamil Nadu with a state level distributed capacity addition of 1,277.50 MW for year 2019-20 (TN Energy department 2021). It is worth mentioning that if gross hourly state load profile is considered instead of hourly net load, the Avoided transmission capacity costs (ATCC) and Avoided generation capacity cost (AGCC) would be overestimated.

The marginal cost of generator to be replaced was taken as INR 4.35/kWh which is the variable cost of Mettur TPS-1 plant, a coal power plant, for year 2019-20 (TNERC 2022).

The solar energy capacity that offers the highest total VODER benefit (INR) would be selected and further considered for sensitivity analysis based on the point of interconnection.

Result

In this section we will discuss the results for the BAU scenario, base case scenario and the sensitivity analysis carried out on the points of interconnection.

Business-as-usual (BAU) scenario

For the business-as-usual (BAU) scenario, where no new solar energy capacity is added to the HT feeder, the details for the voltage violation and distribution line loss are mentioned in table 4.

Table 4: Results for BAU case for Karungalpalayam HT Feeder

Results	BAU
Voltage violation (%)	4.17
Distribution loss (%)	5.59

Note:

1. Voltage violation represents the instances of variation in voltage beyond permissible limits expressed as percentage in a year 1
2. Distribution loss represents the avg. distribution loss percent in year 1

Additionally, it was found that a capacity upgradation for the Karungalpalayam HT Feeder in BAU scenario will be required in the first and the seventeenth year.

Base case scenario

As mentioned earlier, three selected capacities have been considered in base case and the results are shown in the table 5. The base case scenario is defined in reference to the interconnection point of the distributed solar systems, under the base case, solar systems are interconnected at the tail end.

Table 5: Results for the selected solar capacities

Results	BAU	4.50 MW	3.00 MW	2.00 MW
Voltage violation (%)	4.17	3.01	3.22	3.33
Distribution loss %	5.59	4.43	4.67	4.90
1st Upgradation (year)	1st	1st	1st	1st
2nd Upgradation (year)	17th	20th	19th	19th

From table 5 we observe that for all the selected solar energy capacities, percentage of voltage violation ($V\%_{(BAU)}$ = 4.17%) and distribution line losses ($D\%_{(BAU)}$ = 5.59%) were reduced as compared to BAU scenario.

The analysis also assesses the requirement for feeder upgradation, this is based on the number of instances the thermal capacity of the feeder has been exceeded. In case the feeder capacity is exceeded for more than 5 instances in a year, an upgradation in that year is suggested. In BAU case, feeder capacity upgradation is suggested in the first and the seventeenth year of the analysis period (25-year analysis).

As observed in table 6, the VODER benefits for 2 MW solar energy system offers the highest per unit value. Whereas the 4.50 MW solar energy system offers the highest savings in absolute terms (INR/year).

Table 6: Total VODERs savings by solar capacity in year 1

Solar Capacity (MW)	Avoided energy (kWh * 10^6)	VODER (INR/ kWh)	Total savings (INR in Cr)
4.50	6.70	12.84	8.60
3.00	4.48	12.84	5.75
2.00	2.99	12.85	3.84

The VODER benefit consists of network benefit and societal benefit. In table 7, the network benefit and in table 8, societal benefits achieved from the analysis are displayed separately.

Table 7: Network benefits in INR/kWh

Solar Capacity (MW)	ACE	ADCC	ATCC	AGCC	Total
4.50	3.71	0.02	0.04	0.23	4.00
3.00	3.71	0.02	0.04	0.23	4.00
2.00	3.71	0.03	0.04	0.23	4.01

Table 8: Societal benefits in INR/kWh

Solar capacity (MW)	CO2	SO2	NO2	PM2.5	Total
4.50	2.16	1.76	1.34	3.58	8.84
3.00	2.16	1.76	1.34	3.58	8.84
2.00	2.16	1.76	1.34	3.58	8.84

From table 6, it is evident that the total avoided savings are the maximum when the system size is 4.50 MW connected at tail end. Therefore, based on the total VODER benefits achieved from the simulations, the system size with a solar energy capacity of 4.50 MW, interconnected at tail end is selected for sensitivity analysis.

Sensitivity analysis for interconnection point

The interconnection point that Solva tool offers are:

(i) Sending end

(ii) Middle end

(iii) Tail end

Tail end being the location close to the consumer while sending end indicating a location closer to the substation.

In the base case scenario, we have simulated the selected solar energy system at the tail end.

In this section we will discuss results for analysis of 4.50 MW solar energy system and the VODER benefit sensitivity concerning different points of interconnection. The results for the sensitivity analysis for the interconnection point are displayed in the table 9.

Table 9: Sensitivity analysis of interconnection point for 4.50 MW solar capacity

	Interconnection point		
	Tail	Middle	Sending
VODER (INR/kWh)	12.84	12.84	12.82
Voltage violation (%)	3.01	3.28	4.17
Distribution loss (%)	4.43	4.72	5.59
1st Upgradation (year)	1st	1st	1st
2nd Upgradation (year)	20th	20th	17th

The varying distribution line loss percent at respective interconnection points contribute to difference in avoided energy. In this case, interconnecting the 4.50 MW solar system at the tail end of the Karungalpalayam HT feeder results in the highest total VODER benefit.

Conclusion

In this study we have considered to undertake a HT feeder level analysis for Karungalpalayam feeder under Erode substation.

The Solva tool was able to determine the benefits that could be achieved by the integration of distributed solar energy on Karungalpalayam HT feeder.

The analysis was carried out for solar energy systems with three different capacities. In the base case scenario, the solar energy system of 4.50 MW offered the highest total VODER benefit. Further, through the sensitivity analysis on points of interconnection (sending end, middle end, and tail end), it was identified that in this particular case the 4.50 MW solar energy system interconnected at tail end provided the highest total VODER benefit for the Karungalpalayam HT feeder.

However, it must be noted that the benefits from the integration also depend on how load is distributed on the feeder under analysis (sending end, middle end, and tail end).

Conclusion

- Distribution companies may use this methodology to plan future addition of distributed solar energy systems and to identify the interconnection points and capacities that yield the highest network benefit.
- Electricity Regulatory Commissions can refer to the avoided network costs to determine location specific solar feed-in tariffs.
- Policy makers may consider the total VODER benefits - societal benefits and network benefits - to inform legislations and renewable energy programs.
- The Solva tool and this methodology can be used to plan for future integration of distributed solar energy on the distribution network at DT, feeder and substation levels

Disclaimer

The results shown in this report are specific to the Karungalpalayam HT feeder, Erode District, Tamil Nadu, India and are not typical or representative of other distribution feeders and systems.

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