Original Paper

Electric vehicle grid demand:

Potential analysis model and regional architectural planning approach for charging using PVsyst tool

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Abstract. *Electric transportation is a societal necessity to mitigate the adverse effects of local emissions and global climate change. To reach net zero emissions by 2050, countries have examined many strategies to electrify road transport and deploy electric vehicles (EVs). Due to falling lithium-ion (Li-ion) battery pack costs, global electric vehicle sales have grown consistently* *over the past decade and reached 10 million units in 2022. The safe and steady operation of the regional power grid may be compromised by the connection of a sizable random charging load. Therefore, it is crucial to conduct a pre-emptive analysis of the charging load and its potential impact, ensuring that electric vehicles can seamlessly integrate with the grid upon connection. This study employs PVsyst simulation software to assess the feasibility of a 12800 MWp (9000 MWp plus 3800 MWp) PV grid-tied system in India's Delhi-NCR region. The system's affordability and spatial compatibility are considered. The average electrical loads for the Delhi-NCR region have been estimated. The system achieves a 0.846 performance ratio, generating 1648 KWh/KWp/year. About 52.7% of the load has been utilized by the electric vehicle, while the surplus is fed into the power grid. This study emphasizes PV systems effectiveness in alleviating grid peak loads, their cost-effectiveness, low maintenance, and adaptability to peak-time loads.*

1. Introduction

The global total energy consumption is rising radically because of the expanding population, modernization, and individuals' expectation of a rising quality of life. Sector-wise global energy consumption is shown in Figure 1 (IEA, 2023; Hanni et al., 2023). Transportation plays a vital role in the development of any country. The energy demand from transportation is around 26%. Global warming and an impending energy problem have compelled nations to endeavour to become greener and cleaner. Worldwide, interest in electric vehicles (EVs) is growing because of rising gasoline prices and environmental concerns. Electric vehicles (EVs) have emerged as a potentially viable and environmentally sustainable alternative to traditional internal combustion vehicles (ICVs) by utilizing a clean energy source. Electric mobility is thus seen as a societal necessity to mitigate the adverse effects of local emissions and global climate change. Worldwide, countries have explored several pathways to electrify road transport and the deployment of EVs to reach the net zero emissions target in line with the 2050 scenario. The sale of electric vehicles globally has been rising steadily Y-O-Y over the past decade and crossed 10 million units in 2022 due to a consistent drop in lithium-ion (Li-ion) battery pack costs. In 2022, the proportion of electric automobiles among all new car sales was 14%. In 2021, the percentage is approximately 9%, while in 2020, it is less than 5% (IEA, 2023; Petrovic et al. 2020). Figure 2 illustrates the global growth of electric vehicle (EV) stocks from 2010 to 2022 (Petrovic et al., 2020; Haghani et al., 2023), encompassing both battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs) on a global scale. Approximately 66,000 electric buses and 60,000 medium and heavy-duty trucks were purchased globally in 2022, accounting for approximately 4.5% of total bus sales and 1.2% of total truck sales worldwide. The need for electric vehicle batteries is steadily increasing. However, with increased EV sales, there has also been an increase in instances of EV failures (IEA, 2023; Bukya et al., 2023a). The demand for automotive lithium-ion (Li-ion) batteries significantly increased by over 65% and reached 550 GWh in 2022, compared to about 330 GWh in 2021. This development may be attributed mainly to the rise in sales of electric passenger cars, with new registrations showing a 55% increase in 2022 compared to 2021. Fig.3 shows the battery demand scenario and a significant increase in EV global stock in 2022 (IEA, 2023; Bukya et al., 2023b). A deal on climate change was reached in Paris as part of the Ministry of New and Renewable Energy's (MNRE) nationally mandated contributions from the Indian government. As per the agreement, India has committed to generating 40% of its installed power generation capacity from non-fossil fuel sources by 2030. Additionally, India declared that by 2030, the GDP's emission intensity will be 33–35% lower than it was in 2005. Reducing carbon emissions is also pledged for a healthy earth. It was planned at the beginning of 2015 that 175GW of renewable energy installations will be completed by 2022. This 174 GW comes from 10 GW of biomass, 60 GW of wind, 100 GW of solar, and 5 GW of small hydro power (Li et al, 2021; Zhang et al, 2022; Amini et al., 2016).

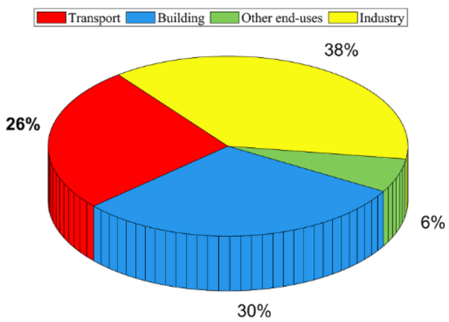

Figure 1. Sector-wise global total energy consumption

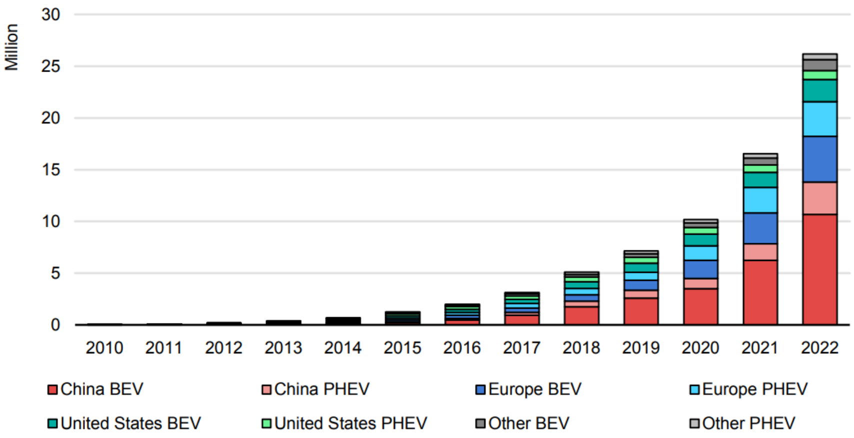

Figure 2. Evolution of the global electric car stock from 2010-2022

The escalating apprehensions regarding global warming and climate change necessitate a heightened focus on the use of clean and sustainable energy sources (Borozan et al., 2022). Renewable energy sources serve as a fundamental basis for planners in formulating a policy framework that effectively addresses energy security and equity, while simultaneously attaining objectives related to the reduction of carbon emissions and mitigation of pollution. Utility size power producers, small power generators, state utilities that include production, transmission, and distribution firms, regulatory and power management organizations, the government, and consumers are major players in the renewable energy (RE) industry (Dominguez-Jimenez et al., 2020; Sharma et al., 2023a; Gao et al., 2021).

Delhi, the National Capital Territory (NCT) of India, is the most populous metropolitan area in the country, receiving a significant influx of individuals from other states, as reported by World Population Review. Rapid urbanization and industrialization have had a negative impact on the environment in recent years. Air pollution in Delhi is a persistent issue that occurs throughout the year (Adaramola, 2014). Significant sources of pollution include Diesel generator sets, car exhaust, road dust, construction dust, open waste burning, light and heavy industries, dust storms and agricultural burning during certain seasons, and sources outside Delhi's administrative boundaries are some of the major causes of pollution (Alsadi et al., 2018; Amin, 2017; Ahmadi et al., 2018), Bollipo et al., 2021). While Delhi's air quality is the subject of the greatest study, publications, and attention (both nationally and internationally), opinions on its causes and effects are divided. The widespread use of electric vehicles (EVs) of all kinds could be one way to address these issues. There are many potential benefits associated with electric mobility. Among these advantages are improved air quality, less reliance on fuel imports, a drop in greenhouse gas (GHG) emissions, a higher plant load factor for the electrical grid, and the chance to lead a rapidly expanding worldwide industry (Almshari et al., 2022; Garg et al., 2024). The Indian and state governments have made several attempts to promote the use of electric cars (EVs), but the adoption rate of EVs is still quite low (Bukya et al., 2023; Garg et al., 2022; Kumar P. et al., 2023; Kumar B. et al., 2015). The need for electricity has increased over the last few decades, and the state of Delhi NCR has built conventional power generation to meet around 25% of the demand. State utilities and other stakeholders are becoming more interested in and focused on renewable energy because it is becoming commercially viable (Manisha et al., 2022; Kiran et al., 2020).

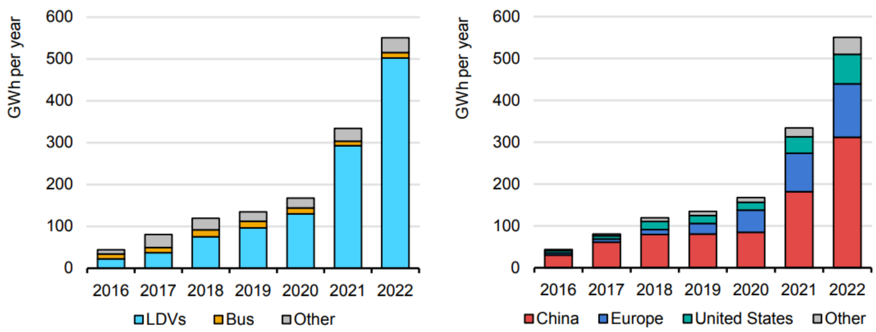

Figure 3. Battery demand by mode and region from 2016-2022

The power is generated at load centres, solar energy can be deployed decentralized, which has the advantage of reducing transmission and distribution losses and saving money on the expense of building additional transmission infrastructure. Efficient methods of utilizing solar energy include decentralized generation via solar rooftop systems, solar electric car charging stations, off-grid applications, and tiny solar power plants at the consumer's end (Sharma et al., 2018). Day by day the use of electric vehicles increasing in Delhi and NCR regions and the charging stations plays very crucial role in future. Thus, the characteristics of EVs mobility demand encompassing modal split, the proportion of mandatory optional trips, trip frequencies, departure times, distance travelled and travel times which plays a pivotal role the requirements for physical infrastructure and the sizing of support facilities within transportation systems. Modal split refers to the distribution of trips among various transportation modes such as private cars and public transit. The ratio of mandatory trips provides the information for the leisure/aborted trips. These trips will determine the optimum cost for every specific distance travelled by the EVs and the desired SOC required for charging/discharging. The socio demographic features such as cost for each trip and the life of EVs battery plays a crucial role in shaping travel preferences and the driving patterns. Thus, analysing these parameters aids in developing targeted strategies for promoting and integrating EVs into the transportation systems and it is one of the challenges for improving the EVs mobility not only in Delhi NCR but also all over the world. The paper will highlight the simulation study of the solar PVsyst for installation of solar charging stations as per load demand of EVs in the region. The main objective is to replace the conventional energy from the utility with rooftop solar PV system and to meet the load requirements. This system of design is simulated by using PV syst and each component is analysed. Also, the current economic and environmental conditions in the proposed roof top solar PV system will be analysed and the results will be compared considering the solar PV system and the utility supply (Trina solar (2020)). The total distance taken for the EV travelling is 30 km, SOC to be 95% for single trip of 30 km and the travel frequency of EVs in Delhi NCR is about 190 km/day and the annual cost is 9811.90.

The following sections of the paper are structured as follows: the second section analyses and models the charging loads of electric vehicles using solar photovoltaic systems and system modelling; the third section leads to a discussion of the results; and the fifth section wraps up the study with limitations and future research opportunities.

2. Analysis and modelling of electric vehicle charging loads based on solar photovoltaic system

There are many complex elements that affect the charging load of electric cars (EVs) in each region. The EV load is impacted by several factors, including the driving behaviours of EV users, the charging infrastructure and grid environment, the performance characteristics of the EVs themselves, and the overall utilization of EVs. These factors all have varying degrees of influence. As illustrated in Figure 4, factors such as the quantity of EVs, charging power, and available battery capacity, among others, determine the total charging demand on the local power grid. Moreover, as charging times become more concentrated, the overall charging load from regional EVs escalates. Consequently, our approach begins with an examination of the forecasted regional EV ownership and EV charging behaviours, ultimately leading to predictions regarding the future charging load of regional EVs. The electric vehicle's frequencies are highest during the morning, evening, and night. During night-time, heavy-duty vehicles are at their maximum as compared to daytime. The fast-charging infrastructure has been considered for EV charging.

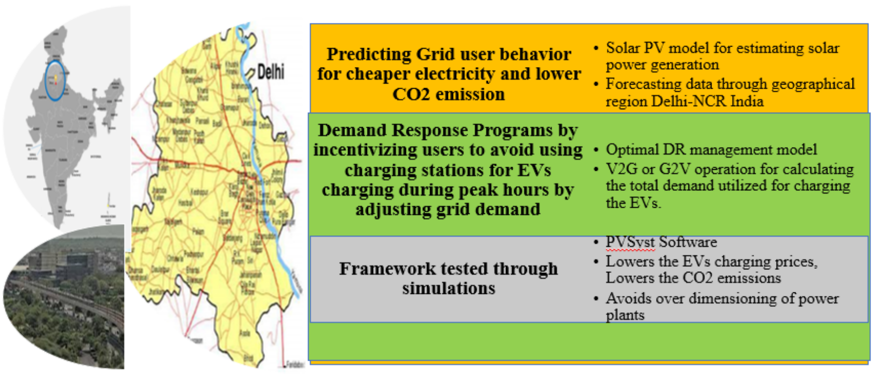

Figure 4. Novel framework for estimating the optimum DR potential)

2.1 Analysis of influencing aspects and EV charging behaviour

A multitude of factors, mostly classified as external and internal value chain factors, impact the forecasting of future ownership of electric vehicles (EVs) within an area. Technical improvements, governmental incentives, and economic conditions are examples of external value chain elements. In contrast, internal value chain factors involve considerations such as charging infrastructure development and consumer behaviours. Detailed analysis of these factors is proposed in the subsequent sections.

2.1.1 Economic Aspects

The automotive industry's progression is intricately linked to economic considerations. A favourable economic climate plays a pivotal role in enhancing the rate of vehicle expenditure. This study has demonstrated that for every 1% increase in per person GDP, or gross domestic product in China, there is a corresponding 0.46% rise in car ownership per one thousand individuals (Shankar et al., 2022; Shankar et al., 2023). Consequently, with China experiencing consistent economic growth, it has regularly held the top position worldwide in terms of electric vehicle (EV) production and sales. While GDP is the customary metric to gauge a region's economic development, it is also influenced by population size (Sher et al., 2015; Weidong et.al, 2007). As a result, this study employs GDP per person as a metric to assess provincial fiscal components.

2.1.2 Policy Supports and Technology developments.

Current study highlights the substantial impact of policy subsidies on the regional electric vehicle (EV) industry. In the nascent stages of EV development in China, the government strongly promoted EVs as an efficient solution to mounting energy and environmental challenges (Sharma et al., 2022, 2023b). This advocacy for EVs materialized through the initiation of the "Automobile Industry Adjustment and Revitalization Plan" in 2009 marked the commencement of the national demonstration initiative for new and energy-efficient vehicles. The central authority allocated assets for subsidization. Concurrently, the Ministry of Finance issued the "Notice on the Pilot Work of Demonstration and Promotion of Energy-Saving and New Energy Vehicles" in same year, by describing the pilot towns' conditions for new energy vehicle subsidies (Sheoran et al., 2023). Bolstered by national policies and surging market demand, various regions introduced their complementary subsidy policies to further incentivize EV development. Consequently, this study examines the average government subsidy index as a key variable affecting the ownership of electric vehicles in each region.

As financial subsidies gradually diminish, the regional electric vehicle (EV) industry is poised to shift from a reliance on policy support to a more market-driven model, as shown in Figure 5. Technological maturity should emerge as the foundational driver of the EV industry's development, with technological innovation playing a pivotal role in guiding consumer purchasing decisions. Currently, ongoing breakthroughs in science and technology continually enhance EV performance, indicating a rapid upward trajectory in technological maturity (Chen et al., 2020; Shu et al., 2017; Yin et al., 2016). Surveys and analyses reveal that consumers place the highest emphasis on specific technical aspects when considering EV purchases, with vehicle range ranking as their primary concern, closely followed by factors like appearance, price, and interior space. In general, the driving range of EVs has consistently been a crucial determinant of their progress, offering a direct reflection of technological development maturity. Consequently, this paper utilizes sustainable driving range as a proxy for technological development factors.

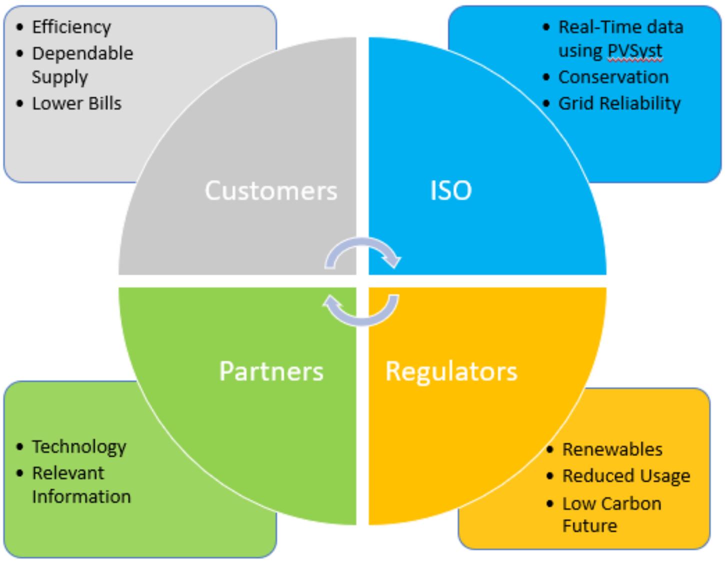

Figure 5. Designed energy strategy with DR and load management

2.1.3 Charging stations and consumers aspects

The advancement of basic charging infrastructure, including regional charging stations and charging piles, makes it feasible to guarantee the efficient operating of electric cars (EVs), improve their convenience, and ultimately increase people's propensity to buy them. Now, China has more EV charging stations overall than any other country in the world, yet there is still a large distribution gap between different regions. Most charging stations can be found in larger, more developed medium and large cities, while they are still relatively rare in certain less developed areas (Ma O et al., 2013; Tushar et al.,2018). Looking ahead, as urban development progresses, the ongoing enhancement of charging infrastructure is expected to encourage a larger populace to embrace and utilize EVs. Consequently, this paper employs the count of public charging piles as a yardstick for assessing charging infrastructure development, deeming it a vital criterion for predicting future EV ownership in a city. The ultimate success of regional electric vehicle (EV) development hinges on consumer attitudes, with consumer acceptance playing a pivotal role in determining the proliferation of EVs on the lane. User acceptance encompasses the willingness of consumers to embrace EVs among various automotive options, influenced by the state of EV technology and the availability of supporting infrastructure. Currently, consumer acceptance of EVs remains constrained. This is largely attributable to the practical challenges, as outlined in this article, such as the intensity of technological advancement and the deployment of charging capabilities. Nonetheless, as these challenges are addressed and knowledge pertaining to EVs becomes more widespread, consumers are expected to enhance their identification of EVs (IEA, 2023), Uzma Dar et al., 2022; Pannala et al., 2020). The proportion of EVs within the overall vehicle population directly reflects consumer acceptance and serves as a vital indicator for forecasting the future prevalence of EVs. Figure 6 describes the various EV service functions based on charging infrastructure and planning.

2.2 System Modelling

A 12,800 MWp grid-connected PV system was used in the study to assess its performance. PVsyst V 7.3.4 is a flexible software tool for designing, analysing, and simulating solar PV systems. This program optimizes PV system designs and predicts energy generation and utilization for charging electric vehicles (EVs) by considering several elements, such as meteorological data, shading, system components, and site-specific information. It is an invaluable tool for solar industry professionals, helping them make well-informed decisions and maximize project efficiency.

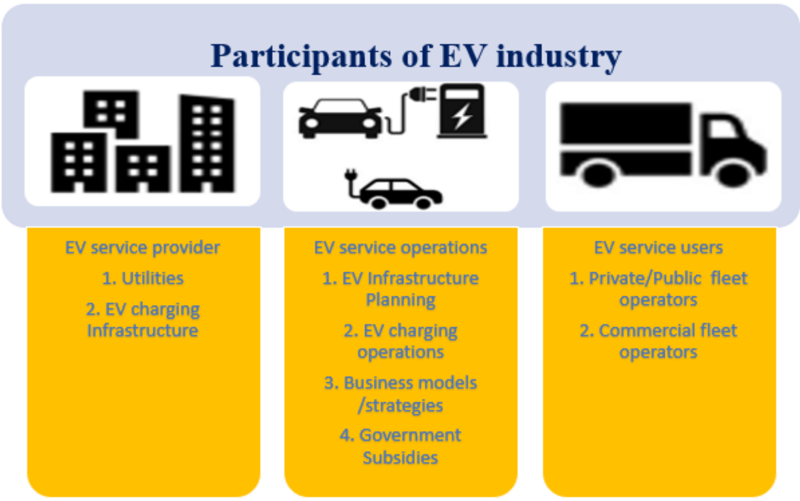

Figure 6. EV service functions

Power losses resulting from radiation, soiling, temperature changes, wiring, inverters, power electronics, interconnections, and grid availability are taken into consideration in the analysis. The system consists of 660 V delta energy inverters and 3,283 Trina Solar photovoltaic modules with an 11,560 MWp capacity. Table 1 shows the technical data of solar panel and Table 2 shows the inverter technical datasheets.

Figure 7 shows the input/output diagram for the energy injected into the grid of 12800 MWp (a) 9000 MWp (b) 3800 MWp.

Model		TSM-DE 19-550Wp Vertex	
Pnom STC Power (Manufacturer)	550 Wp	Technology	Si-mono
Module Size (WxL)	1.096x2.384 m^2	Rough module area (Amodule)	2.61 m^2
Number of cells	2x55	Sensitive area cells (Acells)	2.64 m^2
Specifications for the model (Manufacturer or measurement data)			
Reference temperature (Tref)	25°C	Reference irradiance (Gref)	1000 W/m^2
Open circuit voltage (Voc)	37.9 V	Short Circuit Current (Isc)	18.52 A
Max. power point voltage (Vmpp)	31.6 V	Max. power point current (Impp)	17.40 A
=> maximum power (Pmpp)	549.8 W	Isc temperature coefficient (mulsc)	7.4 mA/°C
One-diode model parameters			
Shunt Resistance (Rshunt)	200 Ω	Diode saturation current (IoRef)	0.040 nA
Serie Resistance (Rserie)	0.12 Ω	Voc temp. coefficient (MuVoc)	-105 mV/°C
Specified Pmax temper. Coeff. (muPMaxR)	-0.34%/°C	Diode Quality Factor (Gamma)	1.00
		Diode factor temper. Coeff. (mu Gamma)	0.0001/°C
Reverse- Bias Parameters, for use in behavior of PV arrays under partial shadings or mismatch			
Reverse characteristics (dark) (BRev)	3.20 mA/V^2	(Quadratic factor (per cell))	
Number of by-pass diodes per module	3	Direct voltage of by-pass diodes	-0.7 V
Model results for standard conditions (STC: T=25°C, G=1000 W/m², AM=1.5)			
Max. power point voltage (Vmpp)	31.3 V	Max. power point current (Impp)	17.58 A
Maximum power (Pmpp)	550.1 Wp	Power temper. Coefficient (mupmpp)	-0.34%/°C
Efficiency (/module area) (Eff_mod)	21.1%	Fill factor (FF)	0.784
Efficiency (/cell area) (Eff_cells)	22.7%		

Table 1. Technical datasheet of 12800 Mega-Watt trina solar panel

Inverter – Solar Inverter DelCEN (3000)			
Model	Solar Inverter DelCEN (3000)		
Commercial Data		**Data Source**	
Protection:	IP65		
Control:	Display operational data	Width	615 mm
		Height	950 mm
		Depth	275 mm
		Weight	84.00 kg
Input characteristics (PV array side)			
Operating mode	MPPT	Pnom ratio (DC:AC)	1.30
Minimum MPP Voltage (Vmin)	610 V	Maximum PV Power (Pmax DC)	7616400 kW
Maximum MPP voltage (Vmax)	800 V	Power Threshold (Pthresh)	3000 KW AC
Absolute max. PV Voltage (Vmax array)	1000 V		
Min. Voltage for PNom (Vmin@Pnom)	640 V		
"String" Inverter with input protections		**Multi MPPT Capability**	
Number of string inputs	36	Number of MPPT inputs	36
Behaviour at Vmin/Vmax	Limitation		
Behaviour at Pnom	Limitation		
Output Characteristics (AC grid side)			
Grid Voltage (Imax)	Triphased 480 V	Nominal AC Power (Pnom AC)	3000 kWac
Grid Frequency	50/60 Hz	Maximum AC Power (Pmax AC)	3300 kWac
Maximum efficiency	98.8 %	Nominal AC current (Inom AC)	5275099 A
European average efficiency	98.4%	Maximum AC current (Imax AC)	12612062 A

Table 2 . Inverter technical datasheet

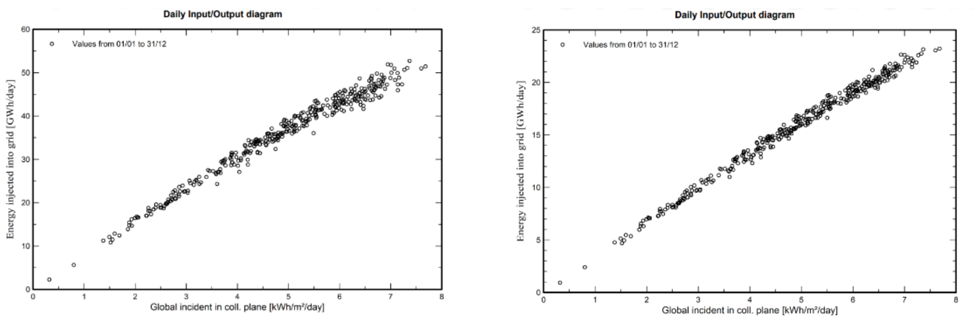

Figure 7 (a) and (b) Diagram showing the energy input and output into the grid of 12800 MWp (a) 9000 MWp (b) 3800 MWp

Thus, 1562500 strings of 36 series modules are constructed using 56250000 solar panels in total. The output of eight 160 KWp inverters with 36 MPPT units is injected into the electrical grid. Fig.8 shows the system output power distribution and the inverter efficiency curve, while Fig.9 shows the various layouts of solar PV arrays. Every module is oriented towards the south at a 0° azimuth and a 15° inclination, devoid of any shading influence.

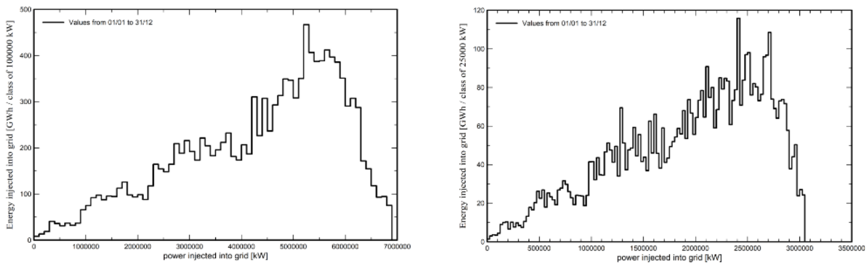

Figure 8 (a) and (b) System output power distribution of 12800 MWp (a) 9000 MWp (b) 3800 MWp.

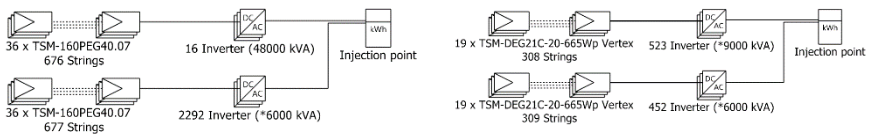

Figure 9 (a) and (b) Single line diagram of Solar PV Array Configuration of 12800 MWp PV grid (a) 9000 MWp (b) 3800 MWp

Figure 10 depicts the demand response variation for 24 hours for 12800MWh solar PV grid. The system shows demand variation for different hours such as 1st hour to 5th hour, 6th hour to 12th hour, 13th hour to 18th hour and 19th hour to 24th hour.

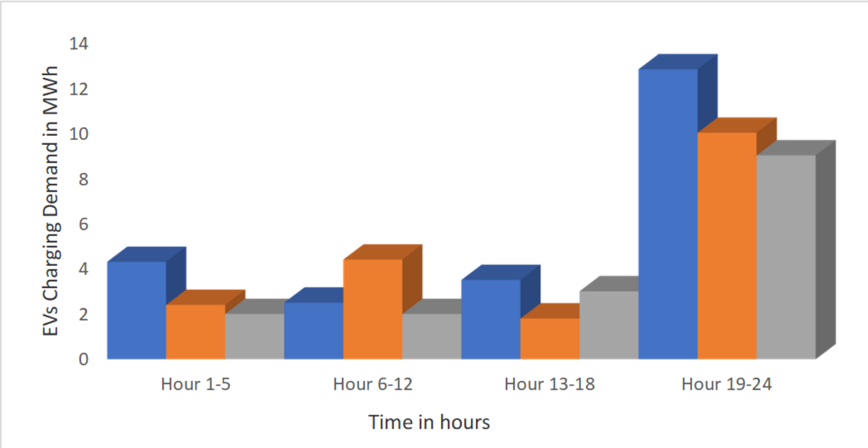

Figure 10 EVs Charging demand for 24-hour scenario using PVSyst

3. Results and Discussion

This study uses a structured charging scenario to anticipate the future charging load of electric cars (EVs) in the Delhi-NCR region of India. This scenario assumes that electric vehicle drivers prioritise their personal driving distance needs and start charging as soon as they get to the charging station. The previous section examined the examination of several variables, such as the length of the charge, the distribution of charging start times, the distribution of the initial state of charge (SOC), and the choice of charging modes for various EV models. In this section, we use the PVSyst tool to simulate the initial charging time and the initial SOC state of electric vehicles, as well as the variation of the demand response due to EV charging loads and the power grid throughout the year. This builds upon the predictions of future EV ownership and a thorough analysis of charging behaviour.

Based on the PVsyst simulation, the highest energy generation happens in March and the lowest energy generation happens in January since the start of the year. The performance ratio and overall assessment of the 12800 MWp based PV load for EV charging are summarised in Figure 11.

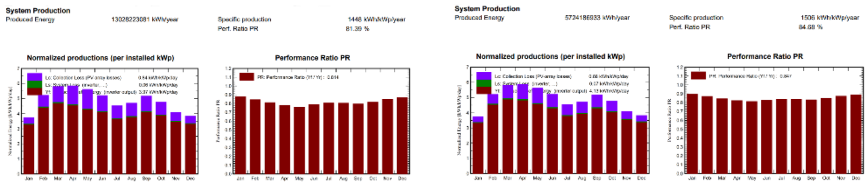

Figure 11 (a) and (b) Performance Evaluation and Performance Ratio of the 12800 MWp Solar PV Plant (a) 9000 MWp (b) 3800 MWp)

Table 3 shows the balances and main results of 9000 MWp. Table 4 shows the balances and main results of 3800 MWp. A power loss diagram for a solar PV plant with a capacity of 12800 MWp is shown in Figure 12. It shows how the power loss varies throughout the year due to various factors such as ambient temperature of 25.43^{0}C, wiring, inverter, power electronics, interconnections, and grid availability. Global horizontal irradiance is 1647.8 KWh /m2, horizontal diffuse irradiation is 891.6 KWh /m2. 1734.6 kWh/m2 is the yearly global efficient value. The grid value is 5724186933 KWh in total. The grid performance ratio is 0.847.

	Glob Hor kWh/m²	**Diff Hor** kWh/m²	**T_Amb** °C	**Glob Inc** kWh/m²	**Glob Eff** kWh/m²	**E Array** kWh	**E_Grid** kWh	**PR** ratio
January	89.58	50.4	13.35	116.0	113.4	932366250	917624802	0.879
February	115.5	50.0	17.69	146.3	143.3	1130978969	1113369353	0.846
March	158.7	70.0	23.72	179.8	175.7	1333569922	1313765104	0.812
April	171.5	82.9	29.76	175.6	171.4	1251906338	1232142073	0.780
May	185.5	97.3	33.62	174.1	169.3	1213984979	1195153040	0.763
June	171.2	99.3	33.25	156.3	151.8	1127976114	1110497310	0.789
July	151.6	100.1	31.45	140.4	136.3	1036717645	1019966362	0.807
August	149.1	92.4	30.43	145.8	141.8	1074264906	1056816869	0.806
September	145.1	74.8	29.18	155.2	151.3	1130874874	1113382935	0.797
October	126.7	72.3	26.74	147.9	144.6	1104921397	1088032495	0.817
November	95.7	55.1	20.52	122.6	119.7	953061904	938823090	0.851
December	87.9	46.8	15.08	118.8	116.2	943253267	928649648	0.869
Year	1647.8	891.6	25.43	1778.6	1734.8	13233876565	13028223081	0.814

Table 3. Balances and main results of 9000 MWp

	Glob Hor kWh/m²	**Diff Hor** kWh/m²	**T_Amb** °C	**Glob Inc** kWh/m²	**Glob Eff** kWh/m²	**E Array** kWh	**E_Grid** kWh	**PR** ratio
January	89.5	50.4	13.35	115.8	113.9	400816717	394453601	0.897
February	115.5	50.0	17.69	146.0	143.8	490977318	483276989	0.871
March	158.7	70.0	23.72	179.7	176.4	585760029	576966190	0.845
April	171.5	82.9	29.76	175.8	172.3	559651541	550712386	0.825
May	185.5	97.3	33.62	174.5	170.5	548057325	539469577	0.814
June	171.2	99.3	33.25	156.7	153.0	500292054	492528189	0.827
July	151.6	100.1	31.45	140.7	137.3	455095905	447760866	0.837
August	149.1	92.4	30.43	146.0	142.6	472366024	464687519	0.838
September	145.1	74.8	29.18	155.2	152.0	499220773	491437362	0.833
October	126.7	72.3	26.74	147.8	145.2	484136854	476694294	0.849
November	95.7	55.1	20.52	122.3	120.1	412169989	405998827	0.873
December	87.9	46.8	15.08	118.5	116.6	406514729	400201133	0.889
Year	1647.8	891.6	25.43	1779.0	1743.6	5815059260	5724186933	0.847

Table 4. Balances and main results of 3800 MWp

Legend: Glob Hor - Global horizontal irradiation, Diff Hor - Horizontal diffuse irradiation, T_Amb - Ambient Temperature Global, Glob Inc - incident in coll. Plane, Glob Eff - Effective Global, corr. for IAM and shadings E Array - Effective energy at the output of the array, E - Grid - Energy injected into grid PR - Performance Ratio

Furthermore, the potential for demand response by electric vehicles (EVs) integrated into the provincial potential grid is influenced by the response frequency of EV users. In this study, it is presumed that the availability of charging infrastructure is adequate, and various situations with differing response prices were established for comparative analysis. For instance, with effective pricing strategies and policy incentives tailored to a 25% response rate, it is possible to reduce the maximum peak load by 7616.4 MW and achieve each day transfer of 9000 MWh of electrical energy. Alternatively, with a 40% response rate and the same incentives, a reduction of 3000 MW in maximum peak load and a daily transfer of 12800 MWh of electricity can be attained. These measures clearly have the potential to mitigate provincial potential grid load variations and helps in managing the overall utilization of load for charging the EVs.

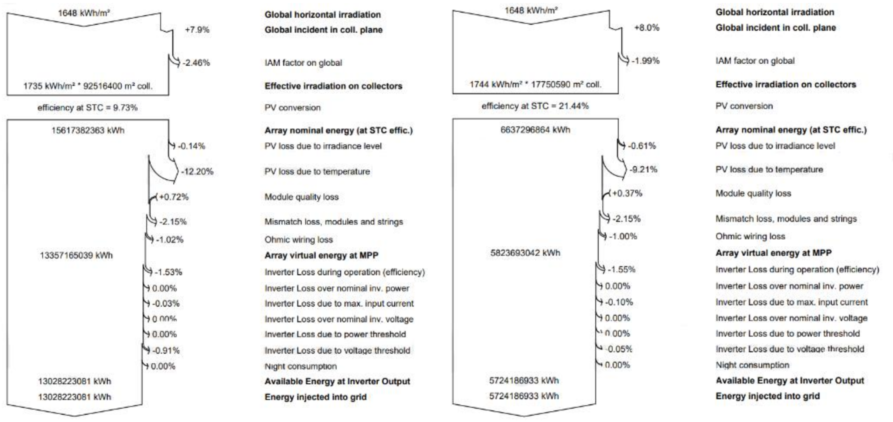

Figure 12 Loss diagram over the whole year for 12800 MWp (a) 9000 MWp (b) 3800 MWp

4. Conclusions

This analysis has laid the groundwork for EV charging load prediction and demand response investigation within the framework of EVs contributing to regional power grids. From this analysis of 12800 MWp solar PV grid, the following inferences can be drawn:

(1) At present, some regional power grids continue to grapple with significant disparities between power supply and demand during specific timeframes. The swift expansion of the electric vehicle industry anticipates a peak electric vehicle charging load in the area projected at 12800 MWp Solar PV system. This electric vehicle charging load is projected to comprise 81.39 % of the provincial potential grid performance ratio at maximum load, considering user charging behaviour without the implementation of optimal load management. The unpredictable fluctuations in this load can pose a detrimental influence on the secure and steady functioning of the energy grid.

(2) The double nature of EVs as both consumers and potential energy sources means they possess significant potential for regulating power loads, enhancing power quality, accommodating renewable energy, and contributing to local power grid demand response through effective

supervision. Moreover, this optimization can play a role in curbing the need for extensive expansion of the provincial energy grid.

(3) The Solar PV-grid tied system 12800 MWp system has been framed by combining the two solar PV grid of 9000 MWp and 3800 MWp solar PV grid as the PVsyst has a drawback that it can form a grid for maximum 9000 MWp in one go. Thus, we combined two grids of different power to obtain a 12800 MWp grid and calculated the demand response and efficiency of the system and obtain better efficiency and low losses.

The next crucial step involves delving deeper into the organized charging and discharging scenarios of electric vehicles, as well as exploring the synchronized communication between electric vehicles and local energy grids for all regions of India. This research builds upon the recent analysis of EV demand response prospective and the established context for EV integration into local energy grid demand response for India Delhi-NCR region. Future work can be extended based on improving the sociodemographic features of EVs like the total distance up to 150 km, calculating the total number of trips travelled by the EVs, aborted trips for the consumers during weekends and the weekdays for obtaining the optimum cost, the travel frequency up to 300 km/day and making it cost effective even for longer distances with the 12800 MWp solar PV grid for EVs charging. This will be a key changer for EV mobility and provides better incentives to the consumers using public transits every day.

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