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# An Optimization Case Study of Hybrid Energy System Based Charging Station for Electric Vehicle on Mettur, Tamil Nadu

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**Abstract**

In the present scenario, the increasing air pollution is a major problem mainly due to the use of petrol and diesel vehicles. To control this air pollution, many countries start using electric vehicle but electric vehicle always need a continuous and good amount of power supply. This power supply is mainly fulfilled using thermal power plants which emit pollution as they provide stable supply as compare to renewable power sources. The solution of this problem is the use of hybrid energy system based charging station where the main power sources are pollution free. The designing and optimizing of the proposed hybrid energy system based electric vehicle charging station using real time data has been done in HOMER software. Moreover, results obtained after simulating the proposed model indicates that the on-grid hybrid charging station system successfully store a large amount of power for electric vehicle charging, fulfils the desired load demand and sales extra power to grid.

***Keywords:*** *Air pollution, Hybrid Energy system, Optimization, Electric Vehicle Charging Station.*

## 1. Introduction

In the present scenario, fossil fuels helps in generating large amount of power in the world which rapidly increasing air pollution in the world. India generates its major portion of power from Coal Thermal Power Plant i.e. 58.3% (powermin.nic.in/en/content/power-sector-glance-all-india, 2018). The main reason behind using them is that they maintain continuity of power supply. On the other hand, individual renewable energy sources are not able to generate fixed amount of power always as well as their power generation cost is high. The renewable energy technologies are improving which result their cost of power generation also reduces in future. This forces the world to shift his interest towards grid connected hybrid energy system that combines two or more energy sources for maintaining continuity of power supply by keeping at least one conventional energy source in backup. Therefore the main goals of this system are the continuity of power generation, minimization of power purchase from grid, reduction in emission and minimization of net present cost. The air pollution is not only increasing due to coal based thermal power plants but also increasing due to the use of fossil fuels in transportation vehicles. This problem can be solved by using electric vehicle. Electric vehicle is mainly an alternative design of an automobile which consists of an electric motor used for converting electric energy stored in battery into mechanical energy that helps to run the vehicle (Guonadottir, 2018). Since the main fuel of electric vehicle is electricity so there is no need of fossil fuel which reduce pollution in the environment but electric vehicle need to charge after travelling fixed amount of distance which is a key disadvantage. This drawback is possible to remove using Battery Swapping Stations (BSS) and Wireless Power Transfer (WPT) technology based stations. An alternative to the normal charging stations is the deployment of Battery Swapping Stations (BSS), which swap a customer's discharged battery with a fully charged one of the same type. These stations could reduce the customers' concerns about long charging times or having enough stored energy to finish a trip (Sarker, 2013). Wireless Power Transfer (WPT) technology based stations helps the electric vehicle in their charging while moving in a road without stopping them. This improves the effective driving range and reduces the volume of battery storage (Vilathgamuwa, 2015). Both these charging stations require a continuous as well as large amount of power supply which is mainly provided by

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conventional energy sources. Therefore there is a need of renewable based charging station but renewable energy is not always present. The hybrid system based charging station used in this paper based on a concept of generating maximum amount of power from renewable energy sources and less amount of power from conventional energy sources so that pollution occur in less amount. In the present scenario of Tamil Nadu, the installed capacity of thermal power plants is 12,479 MW (51%), hydro power plants is 2,208 MW (9%) and other renewable energy sources based power plants is 9,646 MW (40%)(powermin.nic.in/sites/default/files/uploads/Power_For_All_Tamilnadu_Signed.pdf, 2018).This shows that the thermal power plants generate a large part of power with pollution every year. Therefore, it is very necessary to reduce this dependency and for that, hybrid system plays a crucial role. With the help of one large sized hybrid power plant where renewable energy sources contribute a major portion of power, it is possible to shut down nearby thermal power plants of small capacity. This shows the necessity of hybrid energy system based charging station in Tamil Nadu. Many research works has been carried out in designing hybrid systems that produce much less pollution and can efficiently reduce the use of conventional way of electricity generation. In (Zebraoui, 2016) analysis the sizing and feasibility to establish the hybrid energy system to meet the required energy demand using solar and wind power sources, with a minimal investment cost. In (Khan, 2017) proposed the assessment of hybrid off-Grid wind PV system to reduce the emissions with affordable cost. In (Rey, 2017) analyses the modelling of hybrid renewable energy system using HOMER software for Calayan Island in such a way that it fulfill the electricity demand, and it identifies whether it cost effective or not. In (Khadem, 2017) presented a Homer based Hydrogen fuel cell system design for irritation in Bangladesh. The proposed system is used for supplying electricity in the irritation areas.

## 2. Description of the System Data

An on-grid hybrid energy system based charging station designed using HOMER software**.** The proposed hybrid system uses solar power, wind power, hydro power and thermal power. HOMER (Hybrid Optimization Model for Multiple Energy Resources) is a free software application and developed by the National Renewable Energy Laboratory in the United States. It is used to design and evaluate technically and financially the options for off-grid and on-grid power system especially for remote, stand- alone and distributed generation applications **(**Kassam, 2018**)**.

### 2.1 Electric Load Data Information

The average energy consumption of Thanajvur in Tamil Nadu is 12 kWh/day. This load data obtained from UCI machine learning repository website (Kalyani, 2018). On the basis of this data, figure 1 and figure 2 obtained using HOMER software. Thanajvur is a small city in Tamil Nadu. Moreover, the distance between Mettur and Thanajvur is 243 kms or 151 miles **(**alldistancebetween.com, 2018**).** Figure 1 shows the daily average load profile. Figure 2 indicates the average load in months where the peak load found to be 1 kW.

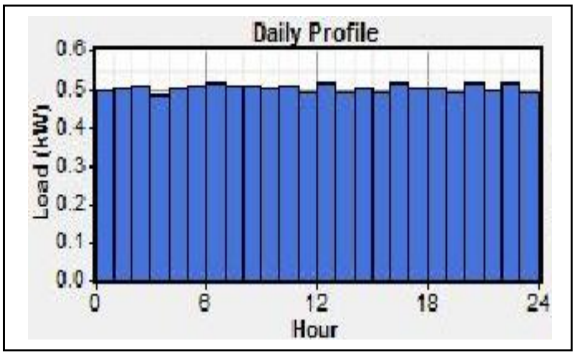


Fig. 1 Hourly Load Profile of Thanajvur

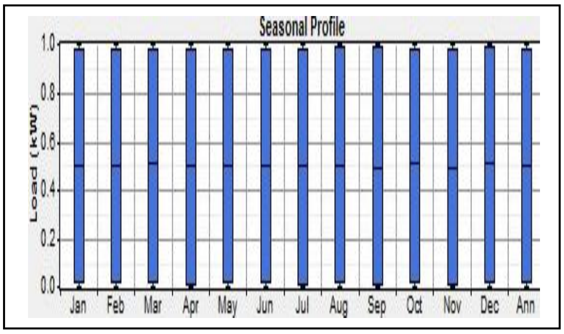


Fig. 2 Monthly Load Profile of Thanajvur

### 2.2 Solar Radiation, Wind Speed, Temperature and Stream flow data of Mettur, Tamil Nadu.

The data of solar radiation, wind speed and temperature are obtained from the database of NASA surface meteorology and solar energy (power.larc.nasa.gov, 2018). The average annual solar radiation found to be 5.12 kWh/$m^2$/day. Figure 3 shows the monthly average data for daily solar radiation and clearness index. Wind speed data found to be at 65 meter above the surface of the earth for the Mettur area. Figure 4 indicates the range of the average wind speed which is from 2.199 m/s to 3.449 m/s. The average annual wind speed found to be 2.75 m/s. Figure 5 indicates the range of the temperature which is from 23°C to 27.7°C. The average annual temperature found to be 25.17°C.

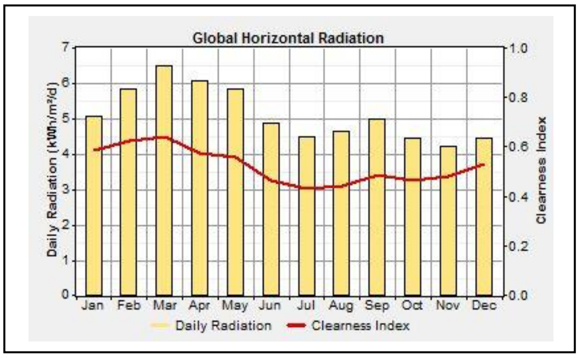


Fig. 3 The monthly average data for daily solar radiation and clearness index.

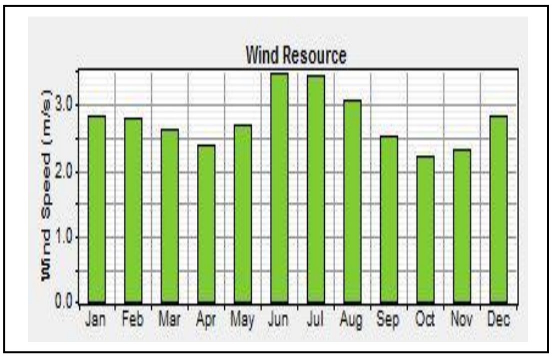


Fig. 4 The monthly average data for wind speed in m/s.

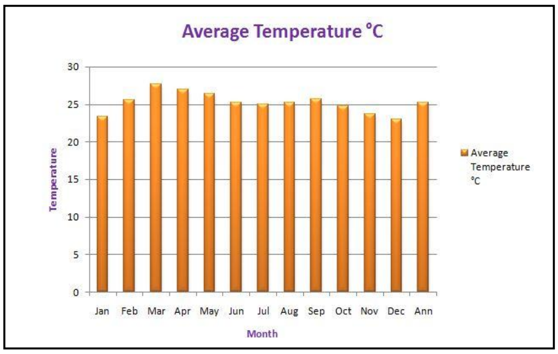


Fig.5 The monthly average data for temperature in degree celsius.

Figure 6 indicates the range of the average stream flow is from 21249.7 L/s to 578498.9 L/s. The average annual stream flow found to be 184384.2 L/s.

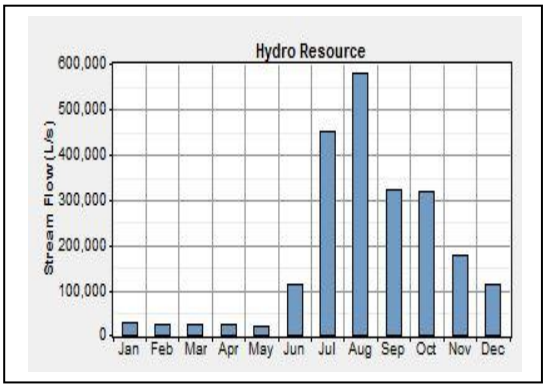


Fig.6 The monthly average data for stream flow in L/s.

## 3. Description of the System Model

The design of the simulation model has done by choosing different components from HOMER software. The model consists of PV power plant, wind farm, generator, power converter, electric load, battery storage, grid connection, hydroelectric power plant, boiler and thermal load as shown in the figure 7. Annual real interest rate of the project is 6% and the project’s lifetime estimated to be 25 yr.

The PV power plant is indicated by PV in the figure 7. The rated capacity of this PV array is 1008,000 kW and operating temperature is 47°C. The capital cost is 2000 $/kW with operation and maintenance (O&M) cost is 20 $/year. The replacement cost of PV array is 2000 $/kW. The lifetime of this PV array is 25 years with efficiency of 15%.

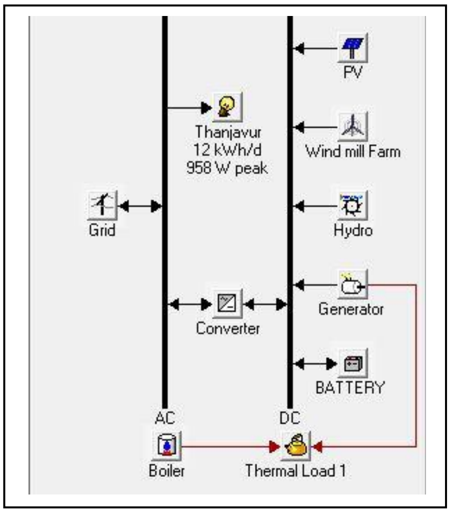


Fig.7 The simulation model of the hybrid energy system based charging station.

The wind farm is indicated by windmill farm in the figure 7. The rated capacity is 15,000 kW. The

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capital cost of five windmills is 4,500,000 $ and the operation and maintenance (O&M) cost of five windmills is 900,000 $/year. The replacement cost of five windmills is 3,500,000 $. The hub height of the turbine is 80 m and its lifetime is 20 years.

The generator used in this system is indicated by Generator in the figure 7. The rated capacity is 200 kW with lifetime 40,000 hours. The fuel used in this generator is natural gas with fuel price is 0.3 $/m$^3$. The initial capital cost is $ 400,000 and the O&M (per op. hour) cost is $ 3.000. The replacement cost is $400,000. It is connected with the boiler and thermal load. All of them together indicate a thermal power plant. The boiler used in this system is indicated by Boiler in the figure 7. The fuel used in this boiler is natural gas with the efficiency of boiler is 80 %. The annual average thermal load is to be 1,659,360 kWh/d. The peak thermal load is 238,258 kW. The load factor is 0.290. Figure 8 shows the daily average thermal load profile.

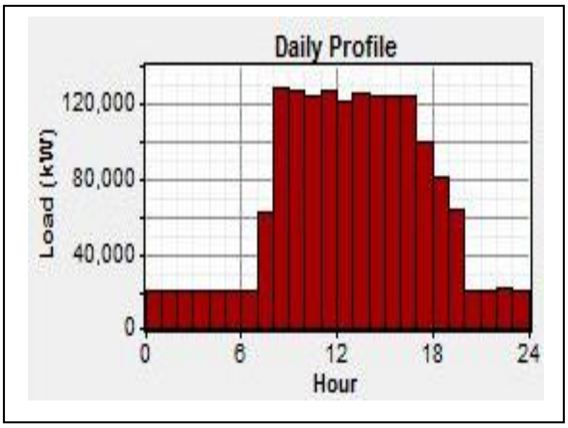


Fig. 8 The daily average thermal load profile in kW.

The hydro power plant is indicated by Hydro in the figure 7. The nominal capacity of hydro power plant is 90,018 kW. The turbine available head is 350 m, design flow rate is 33500 L/s, minimum flow ratio is 0 %, maximum flow ratio is 150 % and the efficiency is 80 %. Its intake pipe head loss is 15%. The capital cost is $ 230,000,000. The replacement cost is $ 115,000,000 and the O&M cost is 51,720,000 $/yr. The lifetime is 30 years.

The battery bank used in this system is indicated by Battery in the figure 7. This battery bank consists of five batteries where each battery has the capacity of 20,400 kWh with nominal voltage of 600 V. The lifetime of the battery is 15 years and the roundtrip efficiency is 90%. The capital cost of one battery is 1598000 $ with O&M cost of 100000 $/year. The replacement cost of one battery is 1400000 $.

The power converter used in this system is indicated by Converter in the figure 7. The lifetime of the power converter inverter is 15 years with the efficiency of 95%. The capital cost is 400 $/kW with O&M cost is 80 $/year. The replacement cost is 400 $/kW. The capacity of the power converter is 1256000 kW. The power converter inverter is parallel with AC generator.

Grid is mainly connected either to give excess power to the grid or to consume power from the grid as shown in figure 7. When there is shortage of power from the renewable or non-renewable energy sources then power consumed from the grid. On the other hand, after satisfying the load demand of an area, if there is an excess of power, then that excess power can be sale to the grid. The grid power price is 0.210 $/kWh and the grid sellback price is 0.16325 $/kWh. The grid net metering system is ON and the net purchases calculated monthly.

## 4. Optimization Result

This section presents the simulation results from HOMER software and discussion of the results. After proper analysis of optimization results of different configuration on the basis of continuity of power supply and cost, one configuration is selected as the most suitable configuration.

Figure 9 shows all the possible configurations of the proposed hybrid system with their initial cost, operating cost ($/yr), total NPC (Net Present Cost), COE (Cost of energy in $/kWh), renewable fraction and natural gas in m$^3$. From the figure 9, it is clear that the third configuration is the most suitable configuration in terms of both the continuity of power supply and cost. This configuration uses all the power sources as well as its overall cost show that the system is economic to use. The total net present cost of this configuration is $ 254,135,376. The levelized cost of energy is -6.554 $/kWh. The operating cost is -199,294,656 $/yr. This configuration has a renewable fraction of 0.84. These results indicate that the configuration is economic to use. The cash flow summary of the proposed configuration for the lifetime is shown in figure 10. It indicates the different types of cost of each component.

| Configurations | Initial capital | Operating cost ($/yr) | Total NPC | COE ($/kWh) | Renewable fraction | Natural gas (m3) |
|---|---|---|---|---|---|---|
| PV (kW), Hydro (kW), GEN (kW), BATTERY ,Converter (kW) & Grid (kW) | $2,756,789,760 | -208,212,896 | $95,130,216 | -2846.37 | 0.84 | 64,116,600 |
| PV (kW), Hydro (kW), BATTERY, Converter (kW) & Grid (kW) | $2,756,389,888 | -208,137,840 | $95,689,568 | -2830.79 | 0.84 | 63,778,072 |
| PV (kW),Windmill Farm, Hydro (kW) GEN (kW),BATTERY, Converter (kW) & Grid (kW) | $2,801,789,952 | -199,294,656 | $254,135,376 | -6.554 | 0.84 | 64,116,600 |
| PV (kW), Windmill Farm, Hydro (kW), BATTERY ,Converter (kW) & Grid (kW) | $2,801,389,824 | -199,219,728 | $254,693,072 | 8.998 | 0.84 | 63,778,072 |
| Hydro (kW),GEN (kW),BATTERY, Converter (kW) & Grid (kW) | $740,790,016 | 56,858,240 | $1,467,629,184 | 21666.34 | 0.62 | 64,116,600 |
| Hydro (kW),BATTERY ,Converter (kW) & Grid (kW) | $740,390,016 | 56,933,324 | $1,468,188,928 | 21681.93 | 0.62 | 63,778,072 |
| Windmill Farm, Hydro (kW),GEN (kW), BATTERY ,Converter (kW) & Grid (kW) | $785,790,016 | 65,776,484 | $1,626,634,240 | 24506.15 | 0.62 | 64,116,600 |
| Windmill Farm, Hydro(kW), BATTERY, Converter (kW) & Grid (kW) | $785,390,016 | 65,851,312 | $1,627,190,784 | 24521.69 | 0.62 | 63,778,072 |

Fig.9 Different Configurations of Hybrid Energy System.

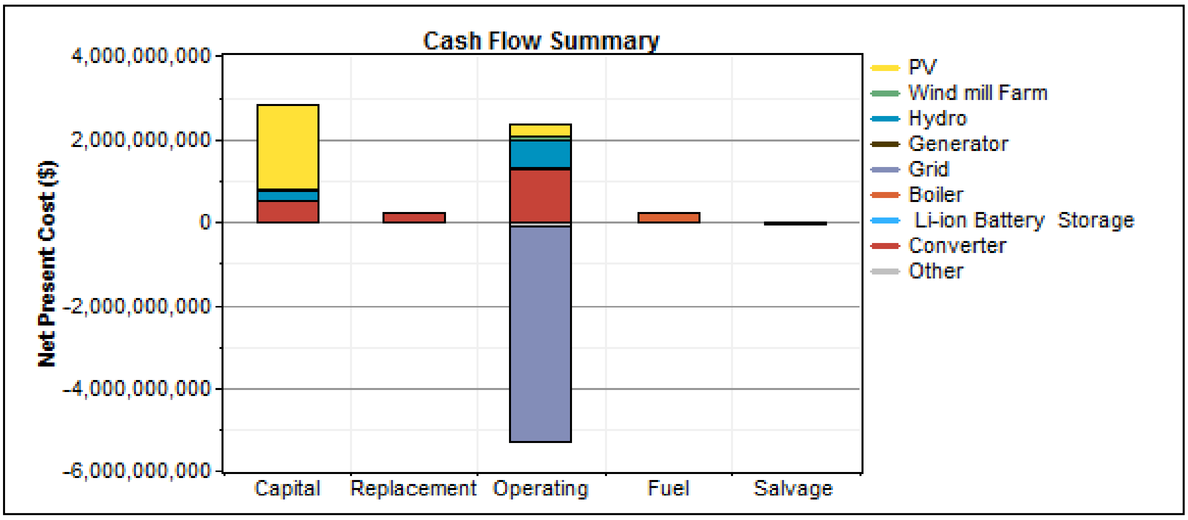


Fig.10 Cash flow Summary of Hybrid Energy System.

The electrical production and consumption summary of the system is given in table 1. In addition, the emissions of the system have given in table 1. Figure 11 shows that the battery storage properties and the statistics. Figure 12 shows the grid purchase (kW) per month and grid sales (kW) per month which indicates that the hybrid plant injects huge amount of power than what it consumes from the grid. And from this figure, it is clear that the grid purchase is zero and the grid sale is very high. Figure 13 shows the battery storage state of charge (%) of one year. It indicates that the battery stores a huge amount of energy every year which can be used for electric vehicle charging.

| Quantity | Value | Units |
|---|---|---|
| Nominal capacity | 102,000 | kWh |
| Usable nominal capacity | 81,600 | kWh |
| Autonomy | 163,199 | hr |
| Lifetime throughput | 15,000,000 | kWh |
| Battery wear cost | 0.492 | $/kWh |
| Average energy cost | 0.000 | $/kWh |

Fig.11 The battery storage properties and statistics.

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Table 1 Optimization Results of Hybrid System

| **Production Summary of System** | | |
|---|---|---|
| **Component** | **Production (kWh/yr)** | **Percent** |
| PV array | 1,797,144,704 | 68.674 |
| Wind Farm | 2,880,749 | 0.326 |
| Hydro power plant | 811,886,528 | 31% |
| **Thermal power plant** | | |
| **Component** | **Production (kWh/yr)** | **Percent** |
| Generator | 1,959,024 | 0.323 |
| Boiler | 502,507,328 | 99.7 |
| Total thermal power | 504,466,368 | 100 |
| **Consumption Summary of System** | | |
| **Component** | **Consumption (kWh/yr)** | **Percent** |
| AC Primary Load | 4,380 | 0.000202 |
| Grid Sales | 2,483,029,760 | 100 |
| Total | 2,483,034,112 | 100 |
| **Emissions Summary of System** | | |
| **Pollutant** | **Quantity** | **Unit** |
| Carbon Dioxide | 1,445,494,272 | Kg/yr |
| Carbon Monoxide | 416,758 | Kg/yr |
| Unburned Hydrocarbons | 0 | Kg/yr |
| Particulate Matter | 11,605 | Kg/yr |
| Sulfur Dioxide | 6,469,198 | Kg/yr |
| Nitrogen Oxides | 2,044,928 | Kg/yr |

| Month | Energy Purchased (kWh) | Energy Sold (kWh) | Net Purchases (kWh) | Peak Demand (kW) | Energy Charge ($) | Demand Charge ($) |
|---|---|---|---|---|---|---|
| Jan | 0 | 206,238,224 | -206,238,224 | 0 | -33,668,388 | 0 |
| Feb | 0 | 195,349,872 | -195,349,872 | 0 | -31,890,866 | 0 |
| Mar | 0 | 224,937,536 | -224,937,536 | 0 | -36,721,052 | 0 |
| Apr | 0 | 199,787,680 | -199,787,680 | 0 | -32,615,338 | 0 |
| May | 0 | 195,947,088 | -195,947,088 | 0 | -31,988,362 | 0 |
| Jun | 0 | 206,246,048 | -206,246,048 | 0 | -33,669,668 | 0 |
| Jul | 0 | 202,496,720 | -202,496,720 | 0 | -33,057,590 | 0 |
| Aug | 0 | 206,010,768 | -206,010,768 | 0 | -33,631,256 | 0 |
| Sep | 0 | 211,652,560 | -211,652,560 | 0 | -34,552,280 | 0 |
| Oct | 0 | 204,995,488 | -204,995,488 | 0 | -33,465,514 | 0 |
| Nov | 0 | 203,755,664 | -203,755,664 | 0 | -33,263,112 | 0 |
| Dec | 0 | 225,612,016 | -225,612,016 | 0 | -36,831,160 | 0 |
| Annual | 0 | 2,483,029,760 | -2,483,029,760 | 0 | -405,354,592 | 0 |

Fig.12 Grid Purchase (kW) per month and Grid Sales (kW) per month of Hybrid System.

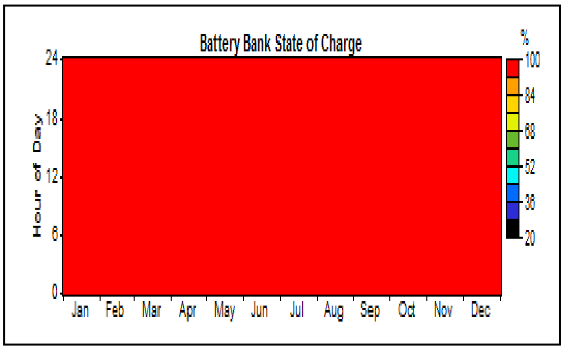


Fig.13 The battery storage state of charge (%) of one year

## 5. Discussion

The optimization results show that the total generated power is in good amount during the whole year. This shows that the continuous power-supplying objective can be easily achieved using this system. This system successfully fulfils the load demand and sells a good amount of power to grid every year. After fulfilling the load demand, this hybrid system easily store a large amount of power in the battery that aimed to used for electric vehicle charging. The paper suggest an effective business strategy of selling the battery storage power for electric vehicle charging in such a way that the prices of energy lowers then the normal energy prices as well as suitable high enough to fulfill the requirement of business. Normally grid purchases power at a very low price and sell at a very high price. So if this system sells its stored power to directly electric vehicle charging station companies or electric vehicle users at a price lower then grid power price. This initiates a new type of business strategy and promotes electric vehicle use in Tamil Nadu.

## 5. Conclusion

The overall conclusion of this analysis is that the hybrid system with its controllers provides a profitable and effective control strategy as well as business strategy in reducing pollution, energy management, energy storage and electric demand fulfillment. In future, the thermal power plant can be replaced by solar thermal power plant and biogas plant to reduce pollution.

## References

[1] ‘Power Sector at a Glance ALL INDIA | Government of India | Ministry of Power', https://powermin.nic.in/en/content/power-sector-glance-all-india, accessed May 20, 2018.

[2] Guonadottir, P. B., Electric vehicles (T-611-NYTI-21652 New Technology): 7-8, https://mafiadoc.com/electric-vehicles_599ef14d1723dd11409074ef.html, accessed June 7, 2018.

[3] Sarker, M. R., Pandzic, H., Vazquez, M. A. O., Electric Vehicle Battery Swapping Station: Business Case and Optimization Model, International Conference on Connected Vehicles and Expo (ICCVE): 289–294, (2013).

[4] Vilathgamuwa, D. M., Sampath, J. P. K., Wireless Power Transfer (WPT) for Electric Vehicles (EVs)—Present and Future Trends, Plug In Electric Vehicles in Smart Grids Power Systems, Springer, Singapore: 33–60, (2015).

[5] 'Power for All Tamil nadu', http://powermin.nic.in/sites/default/files/uploads/Power_For_All_Tamilnadu_Signed.pdf,accessed 3 July, 2018.

[6] Zebraoui, O., Bouzi, M., Sizing and Optimization of a Fully Autonomous Hybrid PV-Wind Power System, International Conference on Electrical Sciences and Technologies in Maghreb (CISTEM): 1–7, (2016).

[7] Khan, K. S., Ullah, Z., Khan, B., Sami, I., Ali, S. M., Mehmood, C. A., Assessment of Hybrid Off-Grid Wind Photovoltaic System: A Case Study of University Campus, International Conference on Energy Conservation and Efficiency (ICECE):16–21, (2017).

[8] Rey, A. L., Santiago, R. V. M., Pacis, M. C., Modelling of a Hybrid Renewable Power System for Calayan Island, Cagayan Using the HOMER Software, IEEE 9th International Conference on Humanoid, Nanotechnology, Information Technology, Communication and Control, Environment and Management (HNICEM):1–6, (2017).

[9] Khadem, T., Billah, S. M. B., Barua, S., Hossain, M. S., HOMER Based Hydrogen Fuel Cell System Design for Irrigation in Bangladesh, 4th International Conference on Advances in Electrical Engineering (ICAEE): 445–49,(2017).

[10] Kassam, A., HOMER Software Training Guide for Renewable Energy Base Station Design. Green Power for Mobile, https://www.gsma.com/mobilefordevelopment/wp-content/uploads/2012/06/HOMER-Software-Training-Guide-June-2011.pdf, accessed June 15, 2018.

[11] Kalyani, K., UCI Machine Learning Repository: Tamilnadu Electricity Board Hourly Readings Data Set' (UCI machine learning repository Website, December 22, 2013) https://archive.ics.uci.edu/ml/datasets/Tamilnadu+Electricity+Board+Hourly+Readings#, accessed February 12, 2018.

[12] 'Distance between Thanjavur and Mettur Dam, All distance between Website', http://alldistancebetween.com/in/distance-between/thanjavur-mettur-dam-8e81b254f5a4ba79930c638185565a0d/, accessed June 14, 2018.

[13] ‘NASA Prediction Of Worldwide Energy Resources’, https://power.larc.nasa.gov/, accessed on 15 July 2018.