Renewable Energy Driven Optimized Microgrid System: A Case Study with Hybrid Solar PV- Battery Storage- Thermal Storage

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Abstract - *A renewable energy driven microgrid system can be designed by integrating with optimally sized renewable energy source such as Solar PV with Battery Energy Storage System (BESS) and Thermal Energy Storage System (TESS). Microgrids integrate Renewable energy source with the other energy mix intelligently. They seamlessly balance the variable output of renewable energy with traditional generation assets. In doing so, the microgrid overcomes the downside of solar energy as they only generate power when the sun shines without any human intervention. In this research study the attempt is made to carry out design engineering of Hybrid Microgrid System to meet Thermal and Electrical demands of the building in optimized and cost-effective way. The design philosophy, Greenhouse gas emission reduction and operating cost savings are demonstrated as the outcome of this study.*

Key Words: **Microgrid, Hybrid Microgrid, Battery Energy Storage, Thermal Energy Storage, Solar PV and Energy Efficiency.**

1. INTRODUCTION

Distributed energy generation through Microgrid refers to a variety of technologies that generate electricity at or near where it is used (end use areas), such as solar panels and combined heat and power. When connected to the electric utility's lower voltage distribution lines, distributed generation from Microgrid can help support delivery of clean, reliable power to additional customers and reduce electricity losses along transmission and distribution lines.

Microgrid provides better power transmission efficiency, power quality, reliability, and security for end users with reduced operating cost. While doing this it also helps to minimize carbon footprint and greenhouse gas emissions by maximizing clean local energy generation.

To work, micro-grids must include three essential components:

1. Locally produced energy: to ensure they can operate independently in the event they are disconnected (photovoltaic panels, wind turbines, cogeneration, heat pumps, biomass plants, hydroelectric turbines, etc.) and an additional back-up supply of energy (power generators).
2. A storage system: batteries, a supply of water for pumped-storage hydroelectricity and, in the future, super-capacitors and a chemical based latent-heat storage system.
3. A smart management system: to ensure the continuous balance between electricity generation and demand.

A microgrid connects to the grid at a point of common coupling that maintains voltage at the same level as the main grid unless there is some sort of problem on the grid or other reason to disconnect. A switch can separate the microgrid from the main grid automatically or manually, and it then functions as an island.

2. LITERATURE REVIEW

Ali Saleh Aziz et al. [1] have done the research on Feasibility analysis of grid-connected and islanded operation of a solar PV microgrid system: A case study of Iraq. They used simulation tool as HOMER software for their study. They concluded that implementing this sort of project can provide clean, economical, and continuous electricity production in countries with daily blackouts.

S Devassy, B Singhn et al. [2] have done the research on Performance Analysis of Solar PV Array and Battery Integrated Unified Power Quality Conditioner for Microgrid Systems. It was experimentational study on existing system. They concluded that their research outcome addresses the issue of the integrating power quality improvement along with the generation of clean energy.

Furat Dawood et al. [3] have done the research on Stand-Alone Microgrid with 100% Renewable Energy: A Case Study with Hybrid Solar PV-Battery-Hydrogen. They used Homer Pro Software for their research. They concluded that that the proposed hybrid energy systems have significant potentialities in electrifying remote communities with low energy generation costs, as well as a contribution to the reduction of their carbon footprint and to ameliorating the energy crisis to achieve a sustainable future.

Andrew Bilich et al. [4] have done the research on Life Cycle Assessment of Solar Photovoltaic Microgrid Systems in Off-Grid Communities. It was theory based analysis and studied Solar PV & BESS based Microgrid system. They concluded that there is significant potential for PV microgrids to be feasible, adaptable, long-term energy access solutions, with health and environmental advantages compared to traditional electrification options.

Mashood Nasir et al. [5] have done the research on Solar PV-Based Scalable DC Microgrid for Rural Electrification in Developing Regions. It was theory-based analysis and studied Solar PV DC Microgrid system. They concluded that proposed highly distributed off-grid solar photovoltaic dc microgrid architecture suitable for rural electrification in developing countries and it is superior in comparison with existing architectures because of its generation and storage scalability, higher distribution efficiency and localized control.

Jakir Hossain et al. [6] have done the research on Modelling and Simulation of Solar Plant and Storage System - A Step to Microgrid Technology. It was Simulation based analysis by using Matlab / Simulink and studied Solar PV & BESS based Microgrid system. They concluded for both the cases of islanded mode and grid-tied mode operation, the performance of the microgrid systems along with the storage unit have been analyzed for the different parameters. All the simulation results have been demonstrated on the virtual platform such as Matlab/Simulink.

3. MICROGRID DESIGN – CASE STUDY

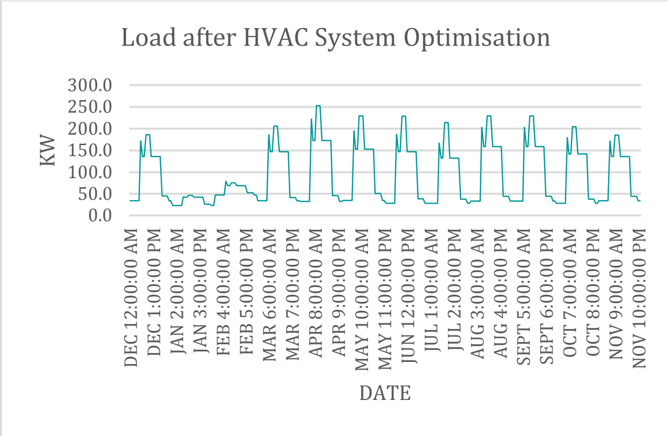
To evaluate the feasibility of proposed Microgrid and present optimized design engineering methodology, a campus of Pillai College of Engineering, New Panvel (Navi Mumbai) has been taken as a case study. The facility consists various energy guzzlers in the form of HVAC system, lighting, Appliances like computers, Printers & workshop equipment's and 75 kWp DC Rooftop Solar PV (SPV). Load profile of the campus is generated from load sheet details and one year electricity bills data.

To develop this Microgrid with the objective of reaching towards Net Zero Energy (NZE) consuming building, emphasis is firstly given on significant reduction of energy consumption, predominantly in HVAC system approx. by 50% as HVAC load forms almost 50% of total facility load.

Proposed replacement of existing Air-cooled Split ACs of total capacity of 200TR with poor specific power consumption 1.35 kW/TR by water cooled central chilled water system with Thermal Energy Storage System (TESS) with the objective of better specific power consumption, 0.70 kW/TR yearly average chiller plant efficiency.

After reduction of energy use, emphasis is given towards switching to renewable energy to meet balance electricity demand with storage. This approach has resulted in significantly reduction in capital investment for SPV & Battery Energy Storage System (BESS) due to their size reduction and thus makes this concept economically sustainable.

The energy vector for proposed Microgrid system consists of suitably sized SPV, BESS and TESS.

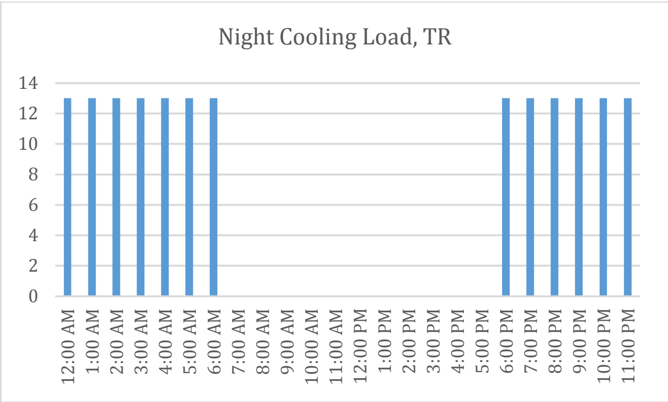


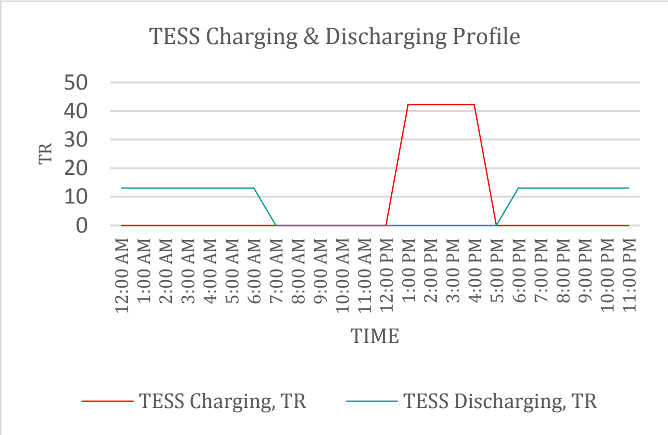
With energy efficiency measures 150,000 kWh consumption reduced which results in facility's total balance cumulative yearly load of 770,000 kWh. The peak load dropped to 250 kW from earlier 300 kW.

Shift of HVAC Night Load to Day Time by using TESS

To make highest use of generated Solar PV energy during daytime, HVAC night load shift is proposed to daytime by using TESS. TESS shall be charged during daytime and discharged during nighttime to meet night cooling load. With this strategy the size of BESS will be significantly reduced as it will not include HVAC load which forms major load of total energy demand. Total nighttime cooling load is 169 TR and corresponding power consumption shall be 208 kW.

Histogram showing typical nighttime cooling load is depicted below. This load profile shall be used for TESS system sizing.





Nighttime cooling through TESS & Day time charging operation is shown in above graph.

TESS Charging time: 1.00 pm to 4.00 pm and TESS Discharging time: 6.00 pm to 6.00 am.

Peak Nighttime hourly cooling load: 13 TR

Operation Time or Cooling demand: 13 Hrs

Water cooled screw brine chiller capacity: 50 TR (1W).

Total Storage Capacity of TESS: 225 TRH

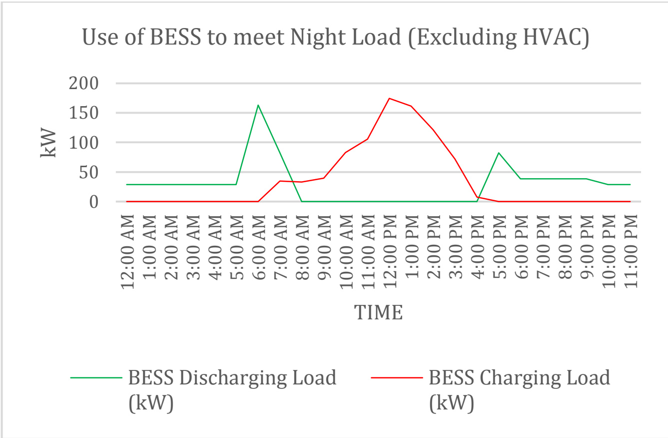
Total Plate Heat Exchanger Capacity Required: 50 TR

Primary side Brine In/out Temp: -2/-5.5 Deg C

Secondary side chilled water In/out Temp: 12/7 Deg C

Shift of Night Load to Day Time by using BESS

To meet the night load by using renewable energy it is proposed to use Battery Energy Storage System. BESS shall be charged during daytime by using SPV system and discharged during nighttime to meet night load excluding cooling load which shall be catered by using TESS.



Peak Nighttime hourly electrical load: 163 kW

BESS Discharge Hours per day: 15 Hrs

BESS Charge Hours per day: 9 Hrs

BESS Useful Energy Storage capacity: 715 kWh

BESS Inverter Capacity: 200 kW

BESS Cycles of Operation: 1 cycle / day

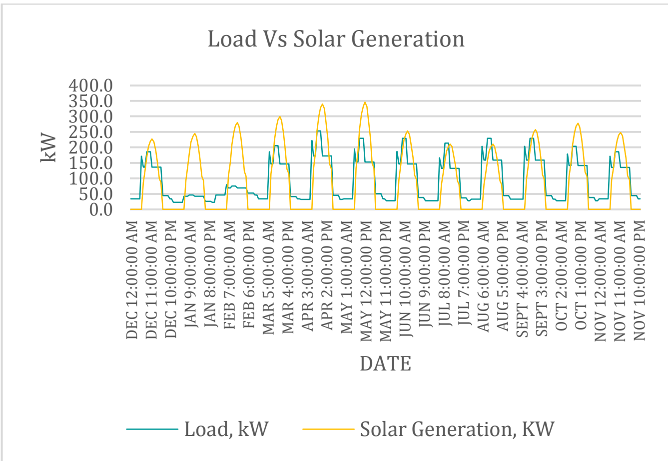
Application: Load Shifting

Type of BESS: Lithium Phosphate

BESS system output voltage: 415 V AC

Use of SPV and BESS to meet the total electrical load the of facility.

The optimized size of SPV system shall cater total electrical demand of the facility with BESS and TESS. Yearly average hourly existing (current) load profile, load profile after energy efficiency measures, BESS and TESS charging discharging profile, and coincidental solar generation is depicted in below table. This data forms the basis of high-level performance of proposed Micro-grid system.



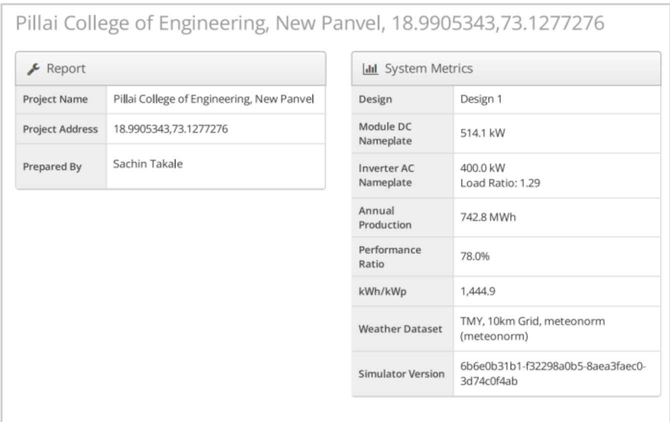
With the installation of 500 kWp, the total available energy would be 743,000 kWh annually.

At most of times, the solar power will be utilized to cater to the facility load, however, in the analysis some curtailed power (excess energy) was indicated in the analysis. As per the analysis, the total excess solar energy (unused energy) is around 61,600 kWh which is 8.2% of the total solar energy generated. With respect to effective PV utilization the renewable energy share would be 90 % of the total plant load including curtailment losses from proposed Microgrid System

Solar PV System Sizing through Helioscope Simulation

Figure: Rooftop Solar PV (500 kWp) Location Layout

The proposed new solar PV modules of total 500 kWp capacity are shown in blue color.



Pillai College of Engineering, New Panvel, 18.9905343,73.1277276

Report	
Project Name	Pillai College of Engineering, New Panvel
Project Address	18.9905343,73.1277276
Prepared By	Sachin Takale

System Metrics	
Design	Design 1
Module DC Nameplate	514.1 kW
Inverter AC Nameplate	400.0 kW Load Ratio: 1.29
Annual Production	742.8 MWh
Performance Ratio	78.0%
kWh/kWp	1,444.9
Weather Dataset	TMY, 10km Grid, meteonorm (meteonorm)
Simulator Version	6b6e0b31b1-f32298a0b5-8aea3faec0-3d74c0f4ab

The total required design solar PV capacity is 514 kWp DC. The cumulative maximum AC output from string inverter is 400 kW. The yearly solar generation of 742.8 MWh is possible as from designed solar PV system. The forecasted performance ratio of solar PV system as depicted from this simulation is 78%

4. FEASIBILITY ANALYSIS

Commercial feasibility analysis of proposed Microgrid system is done by comparing cost required for new installation of microgrid system versus current operating cost of existing conventional system. Existing system means the total power demand to meet facility load is drawn from grid and DG operation in case of Grid failure.

Simulation of selected results for Base case Vs Proposed Microgrid Scenarios

	Results/Scenarios	**Base Case Scenario (BCS)**	**Proposed Microgrid Scenario**
	Optimized Solar PV—DC kWp	X	500
	DG Capacity(kW)	250	X
	BESS (kWh)	X	1000
	TESS Ton-hrs	X	700
	Investment Cost, (INR)	-	
	SPV (500 kWp) system		35,000,000
	BESS System		20,000,000
	Microgrid control system		5,000,000
	Central water-cooled Chiller Plant (150 TR) with TESS		20,000,000
	Total Investment		80,000,000
Economics	Operational Costs savings on electricity import + DG (INR/yr)		16,000,000
	Simple Payback (years)		**5.0**
Renewable Energy	**Renewable Energy (RE) Frac (%)**	6	**90**

5. CONCLUSIONS

The evaluation of proposed Micro-grid system demonstrated that the hybrid BESS-TESS based Renewable Energy system is a favorable and innovative approach for designing towards Net Zero Energy consuming, renewable energy-based Microgrid systems especially for facilities located in Metropolitan regions with high electricity tariff rate and for those establishments who have set aggressive decarbonization goals. The simulation results of this proposed system discovered that it has the very minimum carbon emissions along with the project lifetime of 15 years.

Additionally, it is significantly cost-effective solution compared to 100% Battery energy storage-based solution. The promising simple payback period of 5.0 years makes this system a highly prospective and cost-effective option for the transition towards 100% renewable energy based Microgrid systems.

6. FUTURE SCOPE

Furthermore, evaluation is required for optimal utilization of excess or shortfall in solar PV output considering seasonal changes at micro level to develop 100% renewable driven Microgrid with minimum energy losses.

Refined control logics for seamless operation of proposed solar PV and hybrid storage system.

REFERENCES

[1] Ali Saleh Aziz et al. Feasibility analysis of grid-connected and islanded operation of a solar PV microgrid system: A case study of Iraq; 2020

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