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Optimal Sizing of Building Integrated Hybrid Energy System

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Abstract— ***In this study, an optimal sizing for building integrated hybrid photovoltaic, diesel generator and battery system for zero load rejection is performed. The optimization is obtained by considering the loss-of-load probability (LLP) of the system less than 0.01. For this system, the average daily solar radiation is collected from 'Thondamuthur'region, Coimbatore. The load demand is collected from Civil Department building of Karunya University. The optimization presented in this study aims to calculate the optimum size of a PV array and diesel generator, and battery which examine the minimum system cost. An optimization problem in terms of system unit cost is solved graphically in this study. The results of the optimization show that a photovoltaic/diesel generator choice is more feasible compared to a standalone photovoltaic system or diesel generator system.***

Index Terms—***Diesel Generator, Photovoltaic energy, Renewable energy, Sizing of the system***

I. INTRODUCTION

Photovoltaic (PV) system has played an important role in the solar industry because PV systems are clean, environment friendly energy sources. However, the main drawback of PV systems is their high capital cost compared to that of conventional energy sources. Therefore, many research studies have focused on the optimization of PV systems, such as hybrid PV/diesel generator systems, so that the number of PV modules and diesel generator capacity can be optimally selected. Hybrid PV/diesel generator system size and performance strongly depend on available solar energy. Optimization studies on hybrid PV/diesel systems size can be found in many researches. In [1], genetic algorithm is used to solve the optimization problem in terms of the PV panel cost, battery cost, inverter cost, charge controller cost, diesel generator cost, fuel cost and maintenance costs. However, the optimization problem described in this research has not been subjected to any constraint, and therefore, the availability of the designed system is not defined.

In [2], the optimization of PV-hybrid energy systems is presented. A configuration of the system and a control strategy are optimized by a genetic algorithm. The control of the system is coded as a vector whose components are five decision variables for every hour of the year. However, it is not clear how the optimal vector would be implemented physically in the system or how the variation of weather would change the operation of the system. In [3], a method for the optimal sizing of PV/diesel systems is presented.

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The optimization procedure starts by modeling the diesel generator and then optimizing the PV and battery sizes by determining the minimum number of storage days and the minimum PV array area based on a well-defined weather profile. In [4], dispatch strategies for the operation of a hybrid PV/diesel generator system set points is presented. In addition, a determination of the optimum values of set points for the starting and stopping of the diesel generator to minimize the overall system costs is presented. This optimization is performed using a computer program for a typical dispatch strategy that predicts the long-term energy performance and the lifecycle cost of the system. In [5], a PV/diesel generator hybrid system with battery backup for a village located in Saudi Arabia is suggested. This optimization is conducted using HOMOR software and hourly solar radiation data. Optimization studies on hybrid PV/diesel systems size can be found in [6].

In this research, an optimization for building integrated hybrid PV/diesel generator system for zero load rejection for Karunya University is performed. The optimization is performed considering a loss-of-load probability (LLP) less than 0.01. The optimization presented in this paper aims to calculate the optimum capacities of a PV array and diesel generator, and battery which investigate the minimum system cost. An optimization problem in terms of system units cost is solved graphically in this study. Besides, the optimized system is compared to other energy source choices to highlight its feasibility.

II. SIZING OF PV MODULE AND BATTERY

Sizing means the optimization of the overall performance of PV panel like its size, output etc for acquiring maximum outcome with minimum cost. Excess size causes the loss of cost. For the proper sizing of PV module or panel, the loss of load probability (LLP) should be less than 0.01,which means all demands are satisfied by the system. There is no any loss of load.

In this study, Monthly average solar radiation (KWhr/m2) is collected from Thondamuthur region, where Karunya University is located. The monthly average load demand is collected from Civil Department building of Karunya University.

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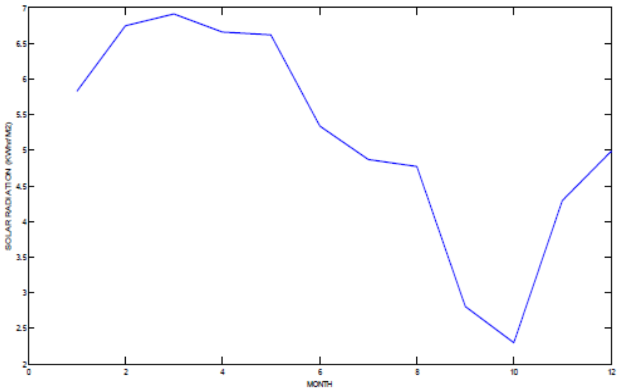

Figure 1: Simulated monthly solar radiation

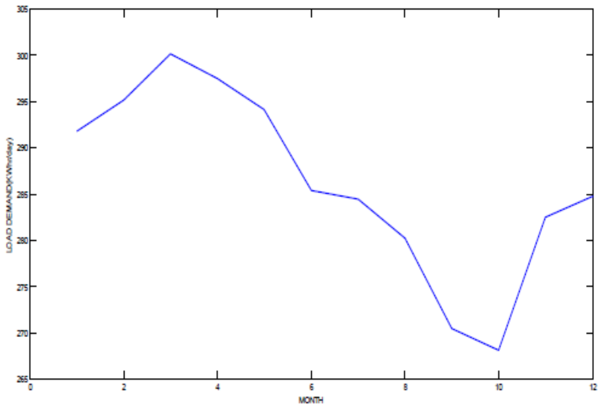

Figure 2: simulated load demand

In this research, the maximum load demand was supposed to be 300 KWhr/day with 33.5 KW as a peak demand.

In general, the sizing of the PV system is represented by calculating the number of needed PV modules and storage battery capacity. However, to achieve a zero load rejection, the loss of load probability (LLP) of the designed system must be less than 0.01. The loss of load probability is given by ,

$$LLP=Ediff/EL \quad (1)$$

The daily energy produced by a PV module/array can be calculated using the formula below,

$$Epv=Apv*Esun*\eta pv*\eta inv*\eta wire \quad (2)$$

Where, Apv is area of PV panel in Meter square, Esun is solar radiations in KWh/meter square, ηpv is efficiency of PV panel, and ηinv and ηwire are the efficiencies of inverter and wire respectively.

The required PV modules and battery capacity can be calculated using some of the formulas below,

$$Ppv=(EL \times Sf)/(\eta s \times \eta inv \times PSH) \quad (3)$$

Where EL is daily energy consumption, PSH is the peak sun hours, ηs and ηinv are the efficiencies of the system components and Sf is the safety factor that represents the compensation of resistive losses and PV-cell temperature losses. On the other hand, the battery capacity can be calculated by,

$$CAh=(EL \times N)/(VB \times DOD \times \eta B) \quad (4)$$

Where VB and ηB are the voltage and efficiency of the battery block respectively, while DOD is the permissible depth of discharge rate of a cell and N is the no:of Number of autonomous days.

III. MODELLING OF THE HYBRID PV/DIESEL SYSTEM

The proposed system consists of a PV array, battery, diesel generator, and inverter. The main load of the proposed system is represented by a building that consumes 300 kWh/day with an 33.5 kW peak load demand.

The system is supposed to have the PV array as a main source with a backup battery while the diesel generator is operated in deficit times. The deficit time is defined as the time in which the instantaneous produced energy form the PV array is not enough to cover the load demand.

Energy to be covered by PV module is calculated as,

$$Enew=EL-EDG \quad (5)$$

Where, EL is the load demand in KWh/day and EDG is energy produced by diesel generator. The energy at the front end of a hybrid PV/diesel system or at the load side is given by,

$$Ediff=Epv-Enew \quad (6)$$

Where, new is the energy to be covered by the pv module. The excess energy is stored in batteries. The energy supposed to be stored in the storage battery is given by

$$Eb= Ediff *battery\ efficiency \quad (7)$$

IV. OPTIMISATION OF HYBRID PV/DIESEL GENERATOR SYSTEM

(a) SIZING GRAPH GENERATION

In this section, the optimum combination of PV array ,diesel generator and then the optimum capacity of the storage battery is obtained. For generalize the obtained results, the following assumptions must be considered:

$$Cdg = Edg / EL \quad (8)$$

$$Cpv = Epv / EL \quad (9)$$

Also, $Cb = Eb / EL \quad (10)$

The optimization algorithm for the proposed hybrid PV/diesel generator system for zero load rejection is given as,

STEP 1: Starts by obtaining the PV module, Diesel Generator specifications & Battery specifications.

STEP 2 : Collect daily solar radiation for a targeted site.

STEP 3 : Obtain the load demand.

STEP 4 : Set range of Diesel generator capacities (zero-load demand).

STEP 5: Calculate the load must be covered by PV array, Enew =EL-EDG

STEP 6 : Applied an iterative loop to calculate the LLP &battery capacity at different values of area & DG capacities.

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STEP 7 : Store the value of PV array area that produces LLP<0.01 at a particular DG value in an array.
STEP 8 : Set the new DG capacity and find the best combination of PV array area.
STEP 9 : Repeat the process until the diesel capacity reaches the load demand.
STEP 10: Store all combinations in an array.
STEP 11: End.

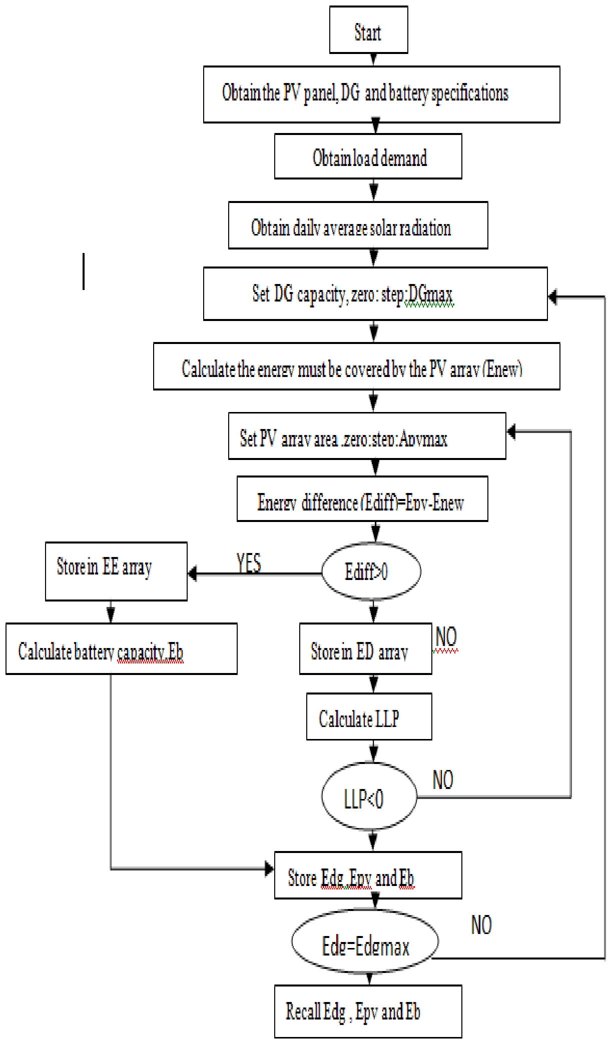

Figure 3: Optimization Algorithm

The algorithm starts by obtaining the PV module and diesel generator specifications. In the second phase of the optimization, a time series of daily solar energy records for the targeted site is needed. These data are used in modeling the PV array based on the fact that the PV array output energy depends on the available solar energy. For obtaining the optimization system, an array containing a PV array capacity, storage battery capacity and diesel generator capacity at LLP less than 0.01 is required. To do so, a range of diesel generator capacities is set. The initial value of this range is supposed to be zero (i.e., there is no existence of the diesel generator and the load is supplied by the PV array only), while the maximum value of the range is supposed to be equal to the load demand. When a diesel generator capacity value is set, the PV array must cover the remaining load demand. That is given by,

$$E_{new}=E_{L}-E_{DG} \quad (11)$$

After this calculation, Apply an iterative loop to calculate the LLP &battery capacity at different values of PV panel area & DG capacities. The range of PV array area is also set from zero to the capacity of PV area that can produce daily energy covers the daily load demand. However, during this loop, only the values of PV array capacity that produce an LLP less than 0.01 are stored in an array. This iterative loop is repeated until reaching the maximum value of the PV array area, and then a new diesel generator capacity is set and the previous loop is repeated until the maximum value of the diesel generator is reached.

(b) COST GRAPH GENERATION

For calculating the optimum pair of diesel generator, pv panel and battery, cost estimation of each pair is required. So, After constructing the desired array, a conversion of this array value using equation (12) is performed to generalize the obtained results.

$$\text{System cost} = \alpha\, PVWp + \beta\, BAh + a\, BAh + \Phi\, ST + \xi\, PE + (\delta\, DGKVA + \mu DGrun + b DGKVA + c DGKVA) + d\, DGKVA + \rho \quad (12)$$

Where, α, β, Φ and ξ are the unit cost of PV module, unit cost of storage battery, unit cost of support structure and unit cost of inverter respectively. δ is the capital cost of diesel generator per KVA and µ is the running cost of diesel generator per KVA. Meanwhile, ρ contains the other costs such maintenance, installation and commissioning and is considered to be constant. And also a,b, c and d are unit cost of charge controller, unit cost of diesel filter unit cost of air filter and unit cost of overhaul respectively.

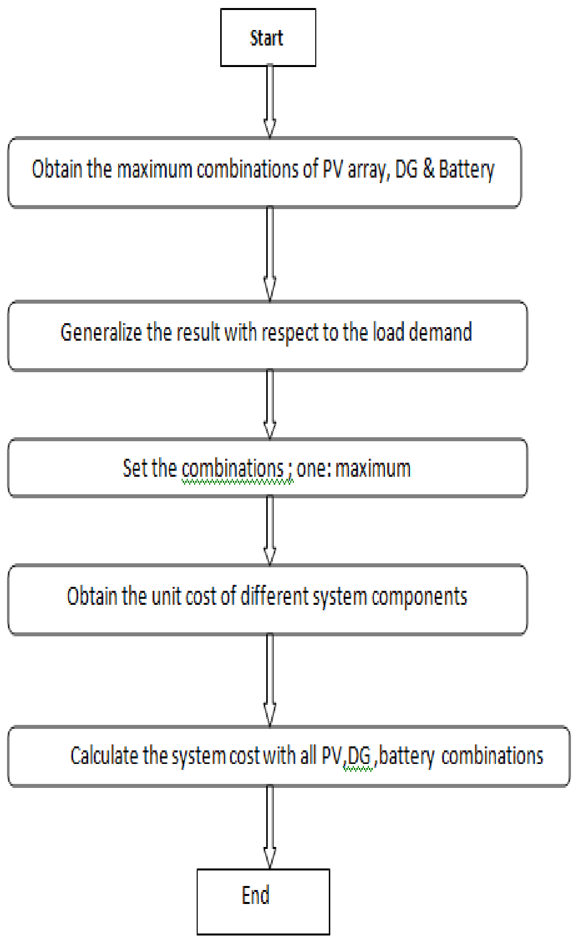

Figure 4: Algorithm for the cost estimation

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Item	Unit cost(Rs)
PV modules	40,000/KW
Support structure	7,000/KW
Storage battery	92.77/Ah
Charge regulator	580/Ah
Inverter	9375/KW
Diesel generator capital cost	16,000/KVA
DG running cost	11.2/KVA
Maintenance cost	1,89,320/year
Diesel filter	780/KVA
Air filter	360/KVA
Overhaul	1500/KVA

Table 1: Unit costs for system components

To determine the optimum pair, there should be normalize both the sizing graph and cost graph (Equalize the axes of both sizing graph and cost graph).

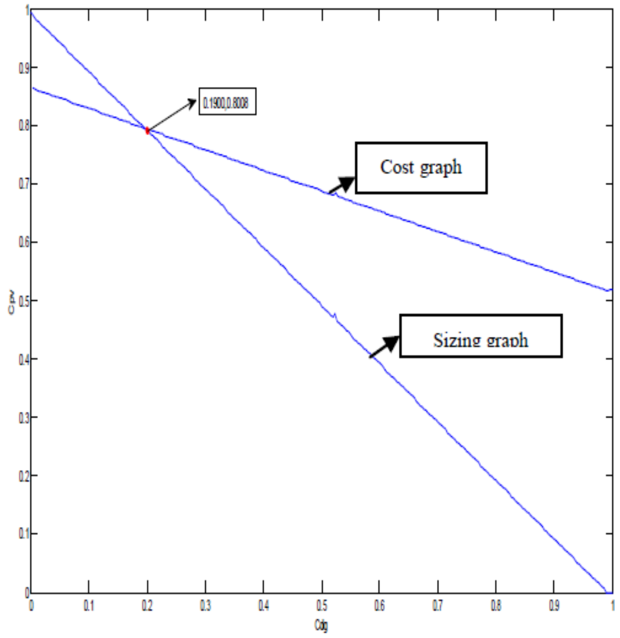

Figure 5: Determination of optimum pair

The meeting point of both sizing graph and cost graph will give the optimum combination of the system based on cost. From the graph, optimum configuration of a PV/DG system is Ca = 0.8008, Cdg = 0.1900 and Cb = 0.0095.Based on the optimization equation, In this optimum value, The energy produced by the system is 300.09KWh/day ,Which is greater than the load demand of the building. So, the system exhibits zero load rejection. The system cost based on the cost function is, 27, 00000 Rs which is obtained from the program.

V.INTUITIVE METHOD

For comparing the hybrid PV/DG system with stand alone photovoltaic and stand alone diesel generator system, the overall cost calculation of all the three systems are essential. Cost estimation of hybrid PV/DG system is obtained from the optimization equation used. For calculating the overall cost of other two systems, intuitive method is used. Intuitive method is the normal method of calculation. That is, addition of all system component costs and other maintenance and installation costs. Here, Intuitive method is used for the cost calculation of standalone photovoltaic system and stand alone diesel generator system.

Item	Unit cost(Rs)	Quantity	Cost(Rs)
PV module	40,000/KW	472.62 KW	18,904,800
Support structure	7000/KW	472.62 KW	33,083,40
Battery	92.77/Ah	110.3 Ah	10,232.5
Charge controller	580/Ah	110.3 Ah	63,974
Inverter	763/KW	40 KW	30,500
		Total cost	22,317,846 Rs

Table 2: Calculation of standalone PV system cost

Item	Unit cost(Rs)	Quantity	Cost(Rs)
Diesel generator	16,266.7/KVA	40 KVA	6,506,66
Diesel	56/liter	93440 liter/yr	52,326,40
Engine oil	35/liter	242 liter/yr	8470
Diesel filter	60 /piece	520 pieces	31200
Air filter	180/piece	80 pieces	14,400
Overhaul	-	-	30,000
		Total cost	59,673,76 Rs

Table 3: Calculation of standalone DG system cost.

VI. CONCLUSION

The recommended configuration of a PV /diesel system is Cpv = 0.8008, Cdg = 0.1900, while the optimum Cb is 0.0095. The optimum system exhibits a minimum system cost with an LLP <0.01. The system cost of standalone photovoltaic system is around 2 crores and system cost of standalone diesel generator system is around 59 lakhs .But The system cost of the proposed system based on the cost function around 27 lakhs. The comparison between this system and two other stand alone systems shows this system is more feasible than others.

REFERENCES

[1] R. Dufo-López, J.L. Bernal-Agustín, ―Design and control strategies of PV–diesel systems using genetic algorithms, Solar Energy 79 (2005) 33–46.
[2] G.C. Seeling-Hochmuth, ―A combined optimisation concept for the design and operation strategy of hybrid-PV energy systems, Solar Energy 61 (1997)77–87.
[3] S.H. El-Hefnawi, ―Photovoltaic diesel-generator hybrid power system sizing,Renewable Energy 13 (1998) 33–40. [4] M. Ashari And, C.V.

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Nayar, —An optimum dispatch strategy using set points for aphotovoltaic (PV)–diesel battery hybrid power system□, Solar Energy 66 (1999)1–9.
[5] Tamer Khatib, A. Mohamed, K. Sopian, M. Mahmoud, —Optimal sizing of building integrated hybrid PV/diesel generator system for zero load rejection for Malaysia□.
[6] Ganguly, D. Misra, S. Ghosh, —Modeling and analysis of solar photovoltaic electrolyzer - fuel cell hybrid power system integrated with a floriculture greenhouse□, Energy and Buildings42 (2010) 2036–2043.
[7] S. Rehman, L.M. Al-Hadhrami, —Study of a solar PV/diesel /battery hybrid powersystem for a remotely located population near Rafha, Saudi Arabia□, Solar Energy 35(2010)46-48.
[8] R. Dufo-López, J.L. Bernal-Agustín, —Design and control strategies of PV–dieselsystems using genetic algorithms□, Solar Energy 79 (2005) 33–46.
[9] G.C. Seeling-Hochmuth, —A combined optimisation concept for the designand operation strategy of hybrid-PV energy systems□, Solar Energy 61 (1997)77–87.
[10] S.H. El-Hefnawi, —Photovoltaic diesel-generator hybrid power system sizing□,Renewable Energy 13 (1998) 33–40.
[11] M. Ashari And, C.V. Nayar, —An optimum dispatch strategy using set points for aphotovoltaic (PV)–diesel battery hybrid power system□, Solar Energy 66 (1999)1–9.
[12] S. Rehman, L.M. Al-Hadhrami, —Study of a solar PVedieselebattery hybrid powersystem for a remotely located population near Rafha, Saudi Arabia□, Solar Energy 35(2010)46-48

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