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# OPTIMISATION OF RENEWABLE ENERGY CONVERSION SYSTEM

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## Abstract

The optimisation of renewable energy technologies costing in remote areas is a crucial aspect of sustainable development and energy accessibility. In order to effectively bring renewable energy solutions to these isolated regions, a comprehensive understanding of the unique challenges and limitations must be considered. Factors such as transportation costs, infrastructure development, and maintenance requirements all play key roles in determining the overall cost-effectiveness of renewable energy technologies in remote areas. By conducting thorough cost-benefit analyses and utilizing innovative financing models, such as pay-as-you-go systems or partnerships with local communities, it is possible to tailor renewable energy solutions to meet the specific needs of these off-grid regions while ensuring long-term sustainability. This optimization process not only expands access to clean and reliable electricity but also contributes to economic growth, environmental conservation, and improved quality of life for inhabitants of remote areas globally.

The harnessing of renewable energy is presented. The methodology is evolved to utilize the available renewable resources in a cost effective manner. In this regard the objective along with the resource and demand constraints are formulated mathematically which are then solved using appropriate method.

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## OBJECTIVE AND DESIGN

The aim is to satisfy all energy needs of remote villages in cost effective, reliable and appropriate manner by a stand-alone renewable energy conversion system/ systems utilizing the locally available energy resources. The renewable energy resources available are:

i Biomass
ii Hydro energy
iii Wind energy
iv Solar energy

The main energy needs of the villagers are:

i Medium grade heat energy for cooking
ii Rotating mechanical shaft energy
iii Electricity at 240 Volts

There are variety of resources and variety of demand. The following two approaches can be applied to achieve the above stated objective:

- Maximization of the investment efficiency. This case suits to the design problem for the area where the resources are in abundance and economic feasibility is the prime consideration.
- Maximization of the amount of energy annually produced from the available resources. This case suits to design problems for the area where the resources are meager and the objective is to exploit the highest possible energy potential of the area in order to cover the local demand [1-4].

Both the approaches have been adopted to achieve above stated objective. The cost minimization can be achieved by optimizing cost based objective function considering demand and resource constraints. For optimization of efficiency the critical issue is to resolve the resource need combination problem and matching of quality of energy resource to the quality of the energy need

[3]. The demand can be met either by converting all form of energies to a single form (say electricity) and then reconvert to the utilizable form of energy for end use. But there will be loss of energy in each of the conversion and result in suboptimal utilization of precious resources. The utilization of resources can be done in a manner that demand of energy for each of the tasks is met by the resources which has the lower cost and higher conversion efficiency. For that the efficiency calculation for each of the energy conversion has been assessed, which is incorporated in the objective equation.

### OBJECTIVE FUNCTION

For the formulation of objective function $\eta_{i-j}$ is expressed as the conversion efficiency of i$^{th}$ resources to satisfy j$^{th}$ energy needs; $w_{i-j}$ is the i$^{th}$ resources to satisfy j$^{th}$ energy needs and is in kWh. $C_{i-j}$ is the cost of i$^{th}$ resource in meeting j$^{th}$ task. The objective function to maximize the overall efficiency is shown in equation 1 [4-5].

$$Maximize(Z_1) = \sum_{i=1}^{m}\sum_{j=1}^{n}\left[\left(\eta_{i-j} \times w_{i-j}\right)\right] \qquad 1$$

While the objective function to maximize the cost is given in equation 2

$$Minimize(Z_2) = \sum_{i=1}^{m}\sum_{j=1}^{n}\left[\left(C_{i-j} \times w_{i-j}\right)\right] \qquad 2$$

*m* and *n* are the number of resources and energy needs respectively.

***Resource Constraints:***The total energy supplied by each of the resources for various energy needs cannot be more than that of its availability. Hence, the sum of a resource is less than or equal to its maximum availability. This can be represented mathematically as expression 3 [2]

$$R_{i,\max} \geq \sum_{j=1}^{n} w_{i-j} \qquad 3$$

For, *i=1,2….m*

***Demand Constraints:*** The sum of the product of energies supplied by various resources and its conversion efficiency for a given energy needs must be equal to the total requirement of the energy for that particular task. It can be mathematically represented as expression 4

$$L_j = \sum_{i=1}^{m}\left(\eta_{i-j} \times w_{i-j}\right) \qquad 4$$

*For j=1,2…..n; $L_j$,*, is the load or energy needs of "*j$^{th}$*" task;

***Non Negativity Constraints:*** All the resources must be equal or greater than zero. Mathematically it can be represented as equation 5.

$$w_{i-j} \geq 0 \qquad 5$$

For *i* =1,2,3…..m. and *j* =1,2,3…..n.

### OPTIMIZATION EQUATIONS

The resources available and load demand as collected from remote areas, is utilized to arrive at the optimal configuration of the integrated renewable energy system (IRES). The wind energy conversion system is not used because of non availability of wind regime in the area. In the village under study the forest residue and waste is found to be the main source of fulfilling cooking need of the villagers and use of traditional *chulha* is prevalent. The use of wood is putting undue pressure in the forest which will increase with the growing population and demand of energy. With this view the forest waste and residue is considered one fourth of the present use. Thus four renewable sources of energies are available – Micro Hydro Power, Biogas, Biomass ( Fuel wood for direct use or Through BES) and Solar PV. The energies requirements to be fulfilled are also three – Electricity, Mechanical and Cooking needs. The equation of efficiency is follows [2] :

Maximize:

$Z_1$= 0.60$MHP_E$+ 0.65$MHP_M$+ 0.42$MHP_H$+ 0.35$BGS_E$+ 0.38$BGS_M$+ 0.45$BGS_H$ +0.35$BES_E$+ 0.38$BES_M$+ 0.45$BES_H$ +0.12$SPV_E$+0.1$SPV_M$

The equation of cost minimization is as follows:

Minimize:

$Z_2$= 1.30$MHP_E$+ 1.30$MHP_M$+ 1.30$MHP_H$+ 2.50$BGS_E$+ 2.50$BGS_M$+ 1.10$BGS_H$ 2.50$BES_E$+ 2.50$BES_M$+ 0.5$BES_H$ + 14$SPV_E$+14$SPV_M$

The cost of BGS for electricity and mechanical energy conversion is taken as that of BES system due to the requirement of engine set. Similarly for biomass to cooking energy conversion the cost of wood collection is assumed to be Rs 0.5 per unit as the cook stove will act as a conversion system.

**Demand constraints**:

$0.60MHP_E+0.35BGS_E+0.35BES_E+0.12SPV_E=124203$ kWh/year

$0.50MHP_H+0.45BGS_H+0.35BES_H=227431$ kWh/year

$0.65MHP_M+0.38BGS_M+0.38BES_E+0.10SPV_M = 9600$ kWh/year

**Resource Constraints**:

$MHP_E+MHP_M+MHP_H \leq 248353$kWh/year

$BGS_E+BGS_M+BGS_H \leq 347395$kWh/year

$BES_E+BES_M+BES_H \leq 126926$kWh/year

$SPV_E+SPV_M+SPV_H \leq 100000$kWh/year

The resource constraints have been arrived at by assuming the load factor for hydro 0.85 and biomas energy system is taken 0.85. For biogas it is assumed to be 0.9. There is no constraint in the quantum of solar insolation that can be harnessed as far as quantity is concerned. The numbers of solar panels are required to be increased as per the insolation available. Hence the solar energy resource is assumed to be 100000 kWh/day for the optimization purpose.

Non- negativity constraints:

$MHP_E \geq 0$; $MHP_M \geq 0$; $MHP_H \geq 0$

$BGS_E \geq 0$; $BGS_M \geq 0$; $BGS_H \geq 0$

$SPV_E \geq 0$; $SPV_M \geq 0$; $SPV_H \geq 0$

The above equations are linear and can be solved by linear programming. Besides, there are two objective functions with conflicting goals which can be solved by applying goal programming [1]. Initially the efficiency of various conversions as estimated and cost of energy in as determined are incorporated to form objective equations. This is then solved using “TORA Software”.

On solving the above linear equations using “TORA SOFTWARE” the results of resource used for satisfying various energy needs are presented in table 1.

**Table 1: The Results of Allocation of Resources as Per Optimization**

| | **Resources Allocated for** | | | **al Resources** |
|---|---|---|---|---|
| | ***Lighting*** | ***(For Cooking)*** | ***Mechanical*** | |
| **Resources** | ***kWh/year)*** | ***kWh/year)*** | ***kWh/year)*** | ***kWh/year)*** |
| **YDRO (MHP)** | 185172 | 48411 | 14770 | 248354 |
| **OGAS (BGS)** | 0 | 347395 | 0 | 347395 |
| **OMASS (BES)** | 0 | 126926 | 0 | 126926 |

| | | | | |
|---|---|---|---|---|
| **OLAR (SPV)** | 109164 | 0 | 0 | 109164 |
| **AL** | | | | 39 |

The electricity of the village is met by the MHP and SPV, Mechanical needs (rotating shaft energy) will be met by MHP and the BES and BGS will cater to the cooking load. The result of optimization prefers hydro and biogas due to their higher efficiencies and lower cost. Solar PV is chosen to the extent of only unfulfilled energy needs that could not be satisfied by the Hydro and biogas. The propose system can provide power to entire village with the renewable energy resources available locally. The optimized allocation of various resources for needs are as follows:

The output of hydro for electricity, $MHP_E$ =185172 *kWh/year*
The use of hydro for Cooking, $MHP_H$ =48411 *kWh/year*
The use of hydro for Mechanical energy needs, $MHP_H$ =14770*kWh/year*
The use of Biomass for Cooking energy needs, $BGS_M$ =347395*kWh/year*
The use of Biomass for Cooking energy needs, $BES_M$ =126926*kWh/year*
The use of Solar PV Energy for electricity, $SPV_E$ =109164 *kWh/year*

From the optimization it is emerged that electricity requirement can be met by MHP (111103 kWh/year) and solar PV (13100 kWh/year). The cooking energy need will be met by Biogas ( 156327 kWh/year), Biomass i.e fuel wood ( 50770 kWh/year) and MHP ( 20332 kWh/year). The mechanical energy requirement of the village can be met by MHP completely.

## CONCLUSION

In conclusion, the optimization of renewable energy conversion systems is a critical component in ensuring the widespread adoption and sustainability of clean energy sources. By carefully examining and fine-tuning various aspects of these systems, such as efficiency, reliability, and cost-effectiveness, we can maximize their overall performance and impact on our environment. It is essential to conduct thorough research, experimentation, and analysis to determine the most effective strategies for optimizing renewable energy conversion systems. Additionally, collaboration between researchers, engineers, policymakers, and industry stakeholders is key to developing innovative solutions that push the boundaries of what is currently possible in the field of renewable energy. By continuously striving for improvement and adaptation in our approach to renewable energy conversion systems, we can pave the way for a more sustainable future for generations to come.

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