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Hibrit güneş-hidroelektrik (GHE) sistemine rezervuar etkisi

Reservoir effect on the hybrid solar-hydroelectric (SHE) system

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Reservoir Effect on the Hybrid Solar-Hydroelectric (SHE) System

Highlights

- *Optimization of the integrated Solar-hydroelectric (SHE) system*
- *Analysis and comparison of the effect of the reservoir on the energy management*
- *Due to the reservoir more installed power and electricity generation became possible*

Graphical Abstract

In this study, an algorithm is meant for outlining the installed power of an integrated SHE system. Reservoir effect on the integrated SHE system is analyzed.

Figure. A. Graphical Abstract

Aim

Explaining the effect of the reservoir of the hydro resource on the energy management of the SHE hybrid system.

Design & Methodology

An optimization algorithm has been designed to figure out the installed power size of the SHE hybrid system, which is planned to be integrated into the present hydroelectric power.

Originality

Suggesting a replacement approach for energy efficiency and management of transformer via integrated hybrid SHE system, and this approach is clarified by a case study.

Findings

In the scenario which is supported by the reservoir effect, more electricity generation, installed power, and capacity utilization rates were achieved.

Conclusion

Energy management of the integrated SHE systems will be provided by a well-designed flow structure of the reservoir.

Declaration of Ethical Standards

The author(s) of this article declare that the materials and methods used in this study do not require ethical committee permission and/or legal-special permission.

Reservoir Effect on the Hybrid Solar-Hydroelectric (SHE) System

Araştırma Makalesi / Research Article

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ABSTRACT

The solar-hydroelectric (SHE) energy system is a renewable hybrid energy system consisting of solar and hydroelectric energy. An optimization algorithm has been designed to work out the installed power size of the SHE hybrid system, which is planned to be integrated into the existing hydroelectric power systems. This designed algorithm provides the optimum installed power with the benefit/cost approach. The value of the hydro cost and also the energy generation is taken from the actual values since it's an existing facility, and also the electricity production and price of the solar power are obtained from the algorithm that works iteratively. This study aims to indicate that more electricity will be produced by regulating water flows due to the reservoir of hydroelectric power plants. Hydro energy enables energy management to be administrated more effectively with the reservoir, which could be a natural enclosure, without using the other energy storage equipment/method. As a result of the study, it's been shown that with the regulation of the hydro facility flows with a reservoir, 180% more solar power capacity installation with 20.9 MW installed power and 12% more electricity production with 75.3 GWh electricity production is provided compared to the unregulated situation.

Keywords: SHE (solar-hydroelectric), energy management, solar energy.

Hibrit Güneş-Hidroelektrik (GHE) Sistemine Rezervuar Etkisi

ÖZ

Güneş-hidroelektrik (GHE) enerji sistemi, güneş ve hidroelektrik enerjisinden oluşan bir yenilenebilir hibrit enerji sistemidir. Mevcut hidroelektrik enerji sistemlerine entegre bir şekilde kurulması planlanan GHE hibrit sistem kurulu güç büyüklüğünün tespiti için bir optimizasyon algoritması tasarlanmıştır. Tasarlanan bu algoritma fayda/maliyet yaklaşımıyla optimum kurulu gücün elde edilmesini sağlamaktadır. Hidro enerji tesisinin maliyeti ve enerji üretimi mevcut bir tesis olduğundan gerçekleşen değerler üzerinden alınmış olup, güneş enerjisinin elektrik üretimi ve maliyeti ise döngüsel olarak çalışan algoritmadan elde edilmiştir. Bu çalışmanın amacı, hidroelektrik santrallerinin sahip olduğu rezervuar sayesinde su akımlarının düzenlenmesi ile daha fazla elektrik üretimi yapılabileceğini göstermektir. Hidro enerji başka bir enerji depolama ekipmanı/yöntemi kullanmadan doğal depolama alanı olan rezervuar ile enerji yönetiminin daha etkin bir şekilde yürütülmesine imkan sağlamaktadır. Yapılan çalışma sonucunda, rezervuarı olan hidro tesis akımlarının düzenlenmesi ile düzenlenmemiş duruma göre 20,9 MW kurulu güç ile %180 daha fazla güneş enerji kapasitesi kurulumuna ve 75.3 GWh elektrik üretimi ile de %12 daha fazla elektrik üretimine imkan sağlandığı gösterilmiştir.

Anahtar Kelimeler: GHE (güneş-hidroelektrik), enerji yönetimi, güneş enerjisi

1. INTRODUCTION

Renewable energy could be a rock bottom and abundant energy source for the planet. However, the capacity factor of renewable energy is not up to fossil-based energy sources. Hydropower plants are among the facilities, the biggest share among renewable energy within the World [1]. Solar power may be a renewable energy type that has the potential to be applied everywhere the planet. In hydroelectric power plants, which are captivated with precipitation, the energy production profile is principally within the spring months, while the minimum of production takes place within the summer months. The solar energy generation profile is that the opposite of the hydropower profile. Therefore, during times when the solar and hydro energy decrease, they support one another. Meaning SHE integrated hybrid systems are the most effective pair among renewable energy types. This case is a barrier to renewable energy implementation decisions. Economically high potential renewable energy system installation delays, thanks to this transformer's limitation. A brand-new transformer building may be an answer, but this is often too expensive and ineffectiveness way. So, efficient capacity utilization usage of an existing transformer is that the most fitted thanks to construct a brand new one.

In general, SHE (solar-hydroelectric) energy systems use an integrated electricity infrastructure. During this study, an integrated structure is recommended for hybridization.

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Integrated SHE systems can show pride in common infrastructures like electrical, grid, connection automation, constructional, mechanical, land, and automation. Hybridization of hydropower and solar energy systems on the identical structure supplies more practical utilization of existent facilities without engendering an extra expenditure for transformer and related electricity infrastructure. In general, the hydropower capacity factor is around 25-40% levels [2] in Turkey. Also, solar power capacity factor rate is between 15-20% levels for fixed mounting systems [2]. SHE systems can form a synergy. SHE system will be installed on canal-top, lake, land, and suitable other areas. An illustration is shown for the SHE system in Figure 1 below.

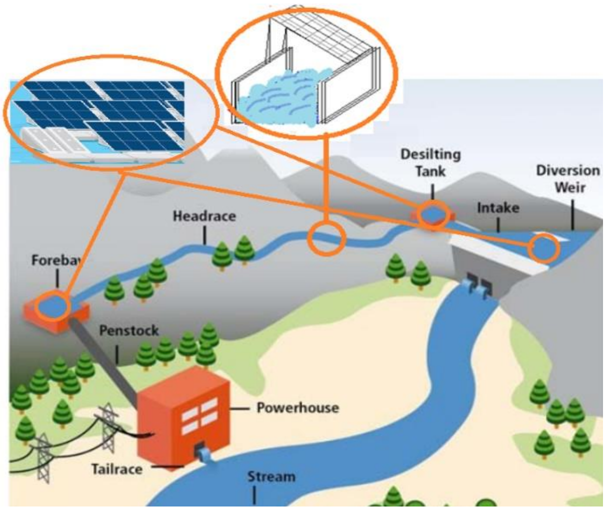

Fig. 1. An illustration of SHE system [3]

Some SHE system applications are implemented everywhere the planet. The body of a dam was covered by PV panels. This application is given in Figure 2 below. The floating solar energy on a basin is given in Figure 3 below. The canal-top solar energy is given in Figure 4 below. The hybridization of hydro and solar power expand everywhere the planet. SHE systems are expected to be a trending topic worldwide shortly soon.

Fig. 2. The Surface SPP of a Dam [4]

Fig. 3. The Floating solar [5]

Fig. 4. The Canal-top Solar [6]

Floating solar power and hydro-solar hybridization are attention getter by the energy sector in recent years. The related literature research is given in below. Mittal et al. [7] emphasized that floating solar energy plants are an innovative approach because of the chance of using them in land conservation and water infrastructures, emphasizing that these facilities can reduce evaporation. It's been stated that with the effective use of those systems for India, a big contribution is made to the energy supply and demand, and therefore the feasibility of a floating solar energy plant with an installed power of 1 MW each are presented to the Kota dam and Kishore Sagar lake in Kota, Rajasthan. Sahu et al. [8] stated that the rise in electricity demand and therefore the increased sensitivity to the environment round the world necessitate the commissioning of large-scale solar energy plants. To conserve valuable soil and water, solar energy systems are stated to be a really attractive choice to install on structures like a dam’s reservoir area, lake surface, wastewater treatment plants, dam’s surface, wineries, fish farms, and canals. Lee et al. [9] emphasized that floating system applications are still not widespread, despite the increasing interest since they'll be placed directly on the water surface. Fereshtehpour et al. [10] stated that the water and energy crises have deepened on a world scale, and it's become a necessity to accommodate them together. Özden et al. [11] emphasized that energy consumption can be met by renewable energy resource couples like wind/solar for energy power station. In this study, artificial neural network is used to determine the control modelling.

Kumar et al. [12] analyzed a canal-top solar energy plant with an installed capacity of 10 MWp in energy, performance, and reliability using data over two years. Koç and Başaran [13] analyzed performance of the hybrid PV/thermal system by using the Matlab/simulink software program. Kapoor and Garg [14] analyzed the prevailing potential solar energy application on a water canal in Roorkee, India. Yenioğlu and Ateş [15] reviewed renewable energy potential of Turkey. Kumar and Kumar [16] compared the canal-top solar energy systems and field-type solar energy systems, which have different environmental conditions. Kumar and Kumar [17] emphasized that the selection of PV technology for solar power systems used on water surfaces is extremely important for large-scale facilities. Javaid and Islam [18] emphasized that energy and water crises are emerging because of the increasing population density in Pakistan, and electricity production costs are on top of in other Asian countries. Sharma et al. [19] stated that among the alternative sources, solar power systems stand out because they will be found easily everywhere. Farfan and Breyer [20] stated that hydroelectric power plants are still the most significant renewable energy source. It's been stated that floating solar energy plants are often installed and 6,270 TWh electricity may be generated. Sanchez et al. [21] stated that the African continent has rich radiation and solar power potential. It's been stated that the installation of floating solar energy plants on these hydroelectric powerhouse dams can make amends for the decrease in energy generation. Selamoğulları [22] analyzed demand characteristics of a greenhouse which supported by renewable energies like solar or wind. Patil et al. [23] emphasized that the interest in renewable energy sources has increased in many regions of the world. It's been stated that solar energy systems have come to the forefront thanks to their falling cost over the years and also the ability to get electricity everywhere.

Rahman et al. [24] emphasized that solar energy facilities, one amongst the renewable energy sources, don't have a noteworthy negative collision on the environment. Erol and Ayasun [25] reviewed the stability of smart hybrid power systems by using the Matlab/simulink software program. Sahu and Sudhakar [26] stated that the interest in solar power systems is increasing day by day, because of land constraints, large-scale field-type solar energy plant installations. Jamalludin et al. [27] studied dynamic modeling of micro-hydro for distributed systems. Golroodbari et al. [28] presented the technical and economic analysis of adding a floating solar energy plant to an existing Dutch offshore powerhouse within the sea. Özcan et al. [29] emphasized the operational period of a hydroelectric power plant for hybridization. Solomin et al. [30] detailed description and explanation of the many floating solar energy plants, and data about usage patterns and style parameters got. The technical, economic, and environmental contributions of hybrid use are presented. Gull and Arshad [31] Singh et al. [32] stated that the Indian city Pondicherry is within the 75th place within the smart cities ranking. A case study is achieved. A floating solar energy plant designed with an installed capacity of two MW is realized with a price of roughly 1.6 million USD and, this investment pay itself back in 6 years. Arıcı and İskender [33] summarized on grid plant's solution which consists of solar energy.

Rauf et al. [34] stated that floating solar energy systems have emerged as another to field-type solar power systems in recent years. Gamarra and Ronk [35] stated that the Texas region of the USA is experienced in electricity and water resources. Bakar and Nandong [36] studied the technical and economic analysis of floating solar energy systems on Bakun lake in Malaysia. Maues [37] explained that a hybrid energy structure consisting of solar and hydroelectric systems contributes to every other in terms of economic efficiency and generation. Elshafei et al. [38] emphasized the difficulties in accessing water and energy. A floating solar energy plant is proposed because the solution to the present problem. Lopez et al. [39] analyzed the scenario during which an offshore wind generation plant with floating solar energy plant. Nebet et al. [40] compared the floating solar effect on dams of Ethiopia. Sharma and Kothari [41] emphasized that 100 GW installed capacity which is 2022's solar energy target may be achieved by floating solar power and pumped storage HEPP hybridization. Jamil et al. [42] performed current, voltage, and power performance analysis of the floating solar. Visas et al. [43] performed the renewable hybrid energy. Dounado et al. [44] administrated an optimization of hybrid energy by the HOMER software program. Augustin et al. [45] demonstrated the performance contribution of a reflector on panel generation. Raina and Sinha [46] presented policy and application proposals for solar power. Akpolat et al. [47] presented an analysis of the roof top solar energy facility. Lee and Choi [48] analyzed roof top energy by a learning-based energy management system. Akrami et al. [49] analyzed power generation values during day and night hours. Palomba et al. [50] presented an analysis of a renewable hybrid energy system, that covers solar and biomass power. Capehart et al. [51] addressed energy control, energy management, economic analysis, financial and data verification techniques during a general scope. Zhang et al. [52] analyzed the efficiency and reliability of renewable energy facilities in an exceedingly distributed system. Özcan [53] reviewed renewable energy appearance of Turkey. Gümüş and Demirtaş [54] reviewed shadow effect on solar energy systems.

Horinov and Horinova [55] stated that energy management requirements on systems and renewable energy. Calvilli et al. [56] focused on the concept of smart grid and energy management. Calik and Firat [57] modelled a consantrated solar power system in İstanbul by using fresnel lens. Selimli et al. [58] analyzed performance of photovoltaic thermal water collectors by empirical and computational. Cuce et al. [59] reviewed fluidal positions in solar energy implementation. Swese and Hançerlioğulları [60] reviewed productivity of photovoltaic thermal facilities by using magnetic material. Ozturk et al. [61], analyzed ZnO material which can be used as candidate material for solar energy applications.

In this study, an integrated renewable hybrid structure is proposed. An algorithm is meant for the installed capacity optimization of the solar a part of the integrated SHE hybrid system. This method can provide transformer efficiency, benefit-cost maximization, and operational simplicity as energy management. So, a developed algorithm and a case study are clarified for reservoir effect on the SHE system. An algorithm functioning on the cost/benefit methodology is designed. Within the scope of this algorithm, a repetitive cyclic design has been made until the step where the foremost optimum installed power solar power may be obtained. The electricity production and price of solar power to be employed in each cyclical step changes. The step gives the best rate of resolve because of the installed power to be applied. For the prevailing hydroelectric station, two scenarios were studied, and also the algorithm was applied. Within the first scenario, the water flows weren't regulated, and within the second scenario, the water flows that reflected the reservoir effect were arranged, and also the algorithm was applied. During this study, an integrated renewable hybrid structure is suggested. An algorithm is intended for the installed capacity optimization of the solar a part of the integrated SHE hybrid system. This technique can provide transformer efficiency, benefit-cost maximization, and operational simplicity as energy management. So, a developed algorithm and a case study are clarified for reservoir effect on the SHE system.

2. MATERIAL and METHOD

The simplified equivalent circuit of PV is given below Figure 5.

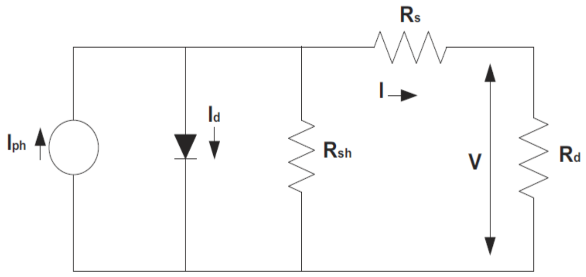

Fig. 5. The simplified equivalent circuit of PV

The energy obtained by PV arrays depends on temperature and radiation. The ability which will be obtained from the PV array is often calculated as follows

$$Ppv = \eta pvg\ Apvg\ Gt \tag{1}$$

While determining the Ppv PV power shown here, the assembly efficiency of PV is expressed as ηpvg, the assembly area of PV is expressed as $Apvg$ (m2) and therefore the amount of radiation is expressed as Gt (W/m2). PV cells are connected to each other series-parallel. The (current) utilized in the PV is regularly linked to the worth of the PV array V (voltage);

$$I = Np\left[Iph - Irs\left[\exp\left(\frac{q(V+IRs)}{AKTNs} - 1\right)\right]\right] \tag{2}$$

$$Irs = Irr\left(\frac{T}{Tr}\right)^3 exp\left[\frac{EG}{AK}\left(\frac{1}{Tr} - \frac{1}{T}\right)\right] \tag{3}$$

where Np is parallel connected cells, Ns is series-connected cells, T is the cell temperature (K), Tr is the cell reference temperature, I is the cell current, V is the cell voltage, Iph is the photocurrent, Irs is the reverse saturation current at temperature T, Irr is the reverse saturation current at Tr temperature, Rs represents series resistance, q is the electron charge (1.6x10-9C), A is the diode ideal factor, K is the Boltzman constant, EG is the bandgap. The Iph changes reckoning on the temperature as follows;

$$Iph = \left[Iscr + ki(T - Tr)\frac{S}{100}\right] \tag{4}$$

$Iscr$ represents the short-circuit current of the cell, ki is the short-circuit temperature coefficient, and S represents the radiation value (mW/cm2). A further parallel resistor is employed within the single-cell model. The I-V characteristics of the PV model are given within the equations below;

$$I = Iph - Id \tag{5}$$

$$I = Iph - Io\left[exp\left(\frac{q(V-RsI)}{AKT} - 1\right) - \frac{V+RsI}{Rsh}\right] \tag{6}$$

Id is the diode current, Io is the reverse saturation current, and Rsh is the parallel resistance. The simplified model is often expressed as;

$$voc = \frac{Voc}{cKT/q} \tag{7}$$

$$Pmax = \frac{\frac{Voc}{cKT/q} - ln\left(\frac{Voc}{cKT/q} + 0.72\right)}{\left(1 + \frac{Voc}{nKT/q}\right)}\left(1 - \frac{Rs}{Voc/Isc}\right)\left(\frac{Voco}{1 + \beta ln\frac{Go}{G}}\right)\left(\frac{To}{T}\right)^{\gamma} Isco\left(\frac{G}{Go}\right)^{\alpha}$$
(8)

voc is the value of Voc, which is that the open-circuit voltage, normalized to the thermal voltage (Vt=nkT /q), n is the ideal factor (1<n<2, α is the nonlinear impact factor, β is the PV dimensionless coefficient, γ is the nonlinear temperature-voltage impact factor. PV systems are formed by connecting one another with series-parallel. PV arrays are expressed as;

$$Parray = NsNpPm \tag{9}$$

$Parray$ represents the facility of the PV array, Ns is the series number, Np is the parallel number, Pm is the utmost power of one PV.

$$Nh = \varrho \, g \, \mu \, Q \, H \tag{10}$$

where, Nh is the hydro power (W), ϱ is the density of water (1,000 kg/m3), g represents the gravity (9.81 m/s2), μ represents the power plant's efficiency (covers turbine,transformer, and generators efficiency), Q represents the project flow (m^3/s), H is the height (m). An integrated SHE system covers hydro and solar energy facilities. The most compelling decision is the installed capacity of solar part in the integrated SHE system. The developed algorithm is given in below Figure 6.

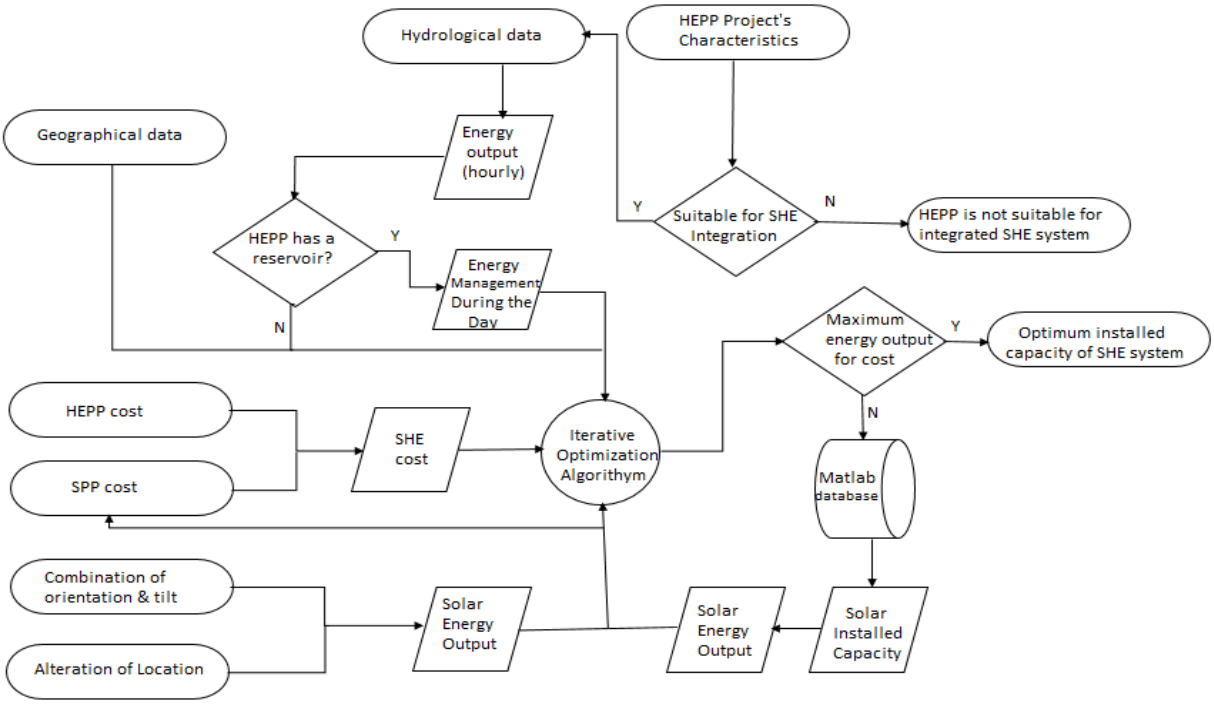

Fig. 6. The SHE optimization algorithm

The algorithm is defined as 5 main sections;

- Hydro
- Solar
- Restrictions
- Cost
- Iterative circular function

An integrated SHE system covers hydro and solar power. Due to geographical conditions, the hydro project's physical characteristics and similar situations will be limited the applicability of hydro energy for an integrated SHE system. So, the primary decision is whether a hydropower plant could be a suitable facility for the integrated hybrid energy system or not. Hydrological and geographical data give a concept for applicability. The premise of generation is defined by hourly within the algorithm. So, flow data of hydropower is obtained hourly. In general, the run of river hydropower facilities has no reservoir. So, generation depends on a rain basis. If a run of river hydropower has water storage, energy management may be achieved easily by this facility. Furthermore, reservoir affects the energy management of the integrated renewable hybrid system. During this study, the reservoir effect on integrated hybrid energy systems is clarified. Solar energy power depends on the panel's current and voltage. Current and voltage are a function of ambient temperature and coordinate radiation. Restrictions determine the algorithm process. Defined restrictions like transformer capacity, maximum available installation solar power areas are the most parameters.

Hydroelectric station costs rely upon the project's characteristics and implementation methodology. It's quite difficult to form a standardization for hydropower facilities, due to the varied hydropower constructions. Some hydropower facilities can have a regulator, dam, tunnel, or canals. So, these constructional structures can affect the price of hydropower plants. Solar energy plant costs are more foreseeable than hydropower. The most cost of a solar energy plant depends on a panel and other related equipment. So, there aren't any drastic changes in solar energy facility costs. The value standards of solar energy provide that it's more predictable than hydropower. An iterative function is that the most vital a part of the algorithm. Matlab interface program is employed as an information storage software program for the algorithm. The optimization function is that the maximum point of the benefit/cost. The benefit describes the income of electricity generation. Total electricity generation is obtained from hourly values of hydro energy and solar energy.

3. RESULTS AND DISCUSSION

A case study is ready for clarification of the reservoir effect on the integrated renewable hybrid SHE system. The calculations are obtained from the algorithm. An existing HEPP facility is chosen for this case study. The hydropower is found in Reşadiye district, Tokat province of Turkey. Project characteristics and Google Maps demonstration is given in below. Long-term average hourly generation data is obtained by company officials for the past 20 years. The actual realizations are taken into account for the energy production amount and investment cost of the existing hydroelectric power plant. Solar power cost parameters are provided by the 2020 IRENA analysis report [62]. The solar energy plant installation cost in 2020 is given as 883,000 USD per MW within the report. Solar energy plant costs for 2021 haven't been announced yet and although a decrease in current costs is anticipated, the material bottleneck, which has begun to be experienced especially because of COVID-19, is anticipated to extend unit costs. Therefore, the value per MW has been accepted as 820,000 USD, reflecting 7% of the decrease in the cost of solar energy in 2020. The designed algorithm cycle compares the energy which will be produced in every 25 kW power range and also the installed power cost to be incurred for this generation. The purpose where the benefit/cost cycle is that the highest provides the integrated hybrid energy capacity where optimum installed power will be obtained.

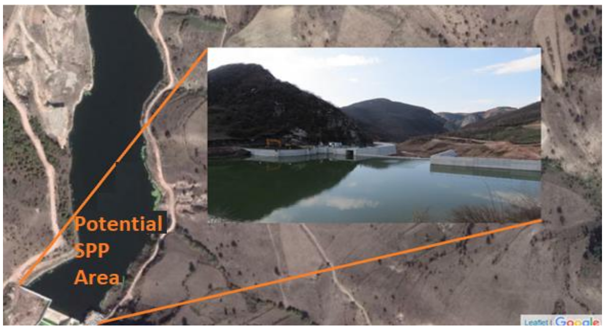

Fig. 7. The existing hydro power plant demonstration

Project characteristics is given in the Table 1 below.

Table 1. The hydropower plant project's characteristics

Installed Capacity	18,777 kW
Turbine Type	Francis
Turbine Quantity	2

The existing hydropower's long-term electricity generation is 52,937 MWh. This generation value states a 32.2% capacity utilization rate of the present hydropower plant. The integrated renewable hybrid SHE system is implemented to the current existing hydropower. During this study, two scenarios are compared. One in all them takes under consideration the long-term flow value of the prevailing hydropower. The opposite scenario considers regulating the prevailing flow. These scenarios are compared as possible installed capacity, electricity generation, and capacity utilization rate. The most acceptances are given in below;

- The economic lifetime of facilities is accepted as 25 years
- Two scenarios are emphasized during this study
- The first scenario is predicated on irregular flows
- The second scenario relies on regulated/managed flows
- The existing hydropower's construction site or near fields are accepted as suitable solar power installation areas
- Hitech Solar HITS-250 M- 60 250 Watt PV module data sheet is employed as solar energy parameters
- The meteorological data is obtained from the Turkish State Meteorological Service
- The daily-based radiation is obtained from the NASA website.
- The hourly based radiation is obtained from the daily radiation by the empirical method
- The installed capacity is obtained from the algorithm
- The electricity generation is obtained from the algorithm
- The existing hydropower plant's implementation cost is accepted as realized expenditure – 32 million USD-
- The solar energy unit cost is accepted as 820,000/MW
- 1000 steps last the iterative trigonometric function of the primary scenario
- 1500 steps last the iterative trigonometric function of the second scenario
- Unit step size is defined as 25 kW
- The total electricity generation is restricted to 18.777 MW by hourly
- The electricity sales price is accepted as 73 USD/MWh. The existing hydropower's long-term irregular flow-based electricity generation is created by the algorithm.

The benefit/cost optimization indicates that 383. step is that the maximum point of the algorithm for the 1st scenario (irregular flows). Regarding the 383. Step, 9.575 MW installed capacity solar power facility will be applicable for 18.777 MW installed capacity existing hydropower plant. The whole electricity generation and benefit/cost optimization are given in Figure 8 below.
The existing hydropower's electricity generation, solar energy electricity generation, and total integrated renewable hybrid SHE system's electricity generation are given in Figure 9 below. The black line is defined as transformer capacity. So, if the entire energy is over then this black line, the power cannot access the grid. The blue area represents hydropower's electricity generation. Approximately, 52,937 MWh is generated by the prevailing hydropower plant. The red bars are defined as

solar power generation, the delimitation is symbolized as SHE system generation. Solar power can generate 14,922 MWh of electricity. Because of the transformer limitation, 14,436 MWh may be available for electricity generation of the integrated renewable hybrid SHE system. As is additionally understood from Figure 9 below, transformer limitation is climbed over by total electricity generation of the integrated SHE system within spring . Regarding the entire electricity generation, this leakage is comparatively small. It's understood that hydropower's minimum electricity generation period is that the maximum electricity generation period of solar energy. So, it's clear that solar and hydro energy can make amends for their electricity generation shortcoming period. As a subcomponent of integrated renewable hybrid SHE system, solar and hydro energy may be identified as natural compensation couples. The capacity utilization rate of existing hydropower is around 32.2%. The full electricity generation of a facility is calculated as 67,373 MWh. Thanks to this integrated renewable hybrid SHE system implementation, the capacity utilization rate of the ability can increase to 41% level.

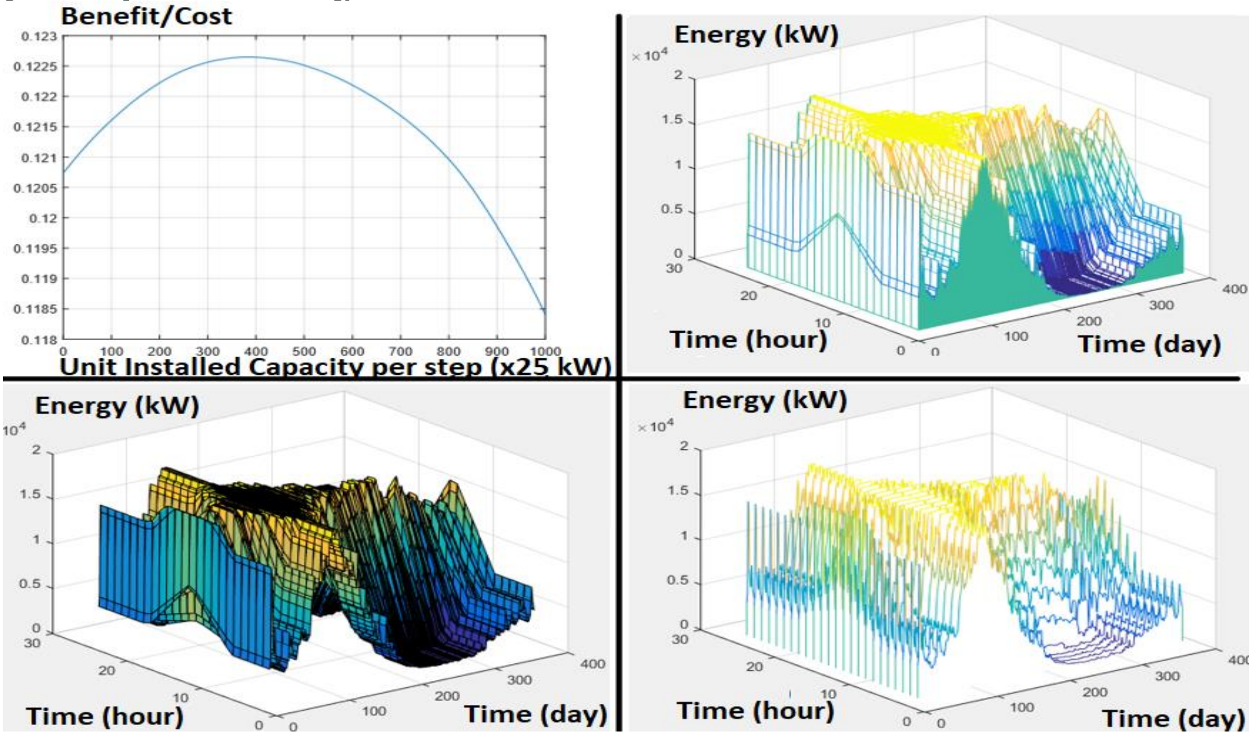

Fig. 8. The optimization of the irregular flows and energy output (1st scenario)

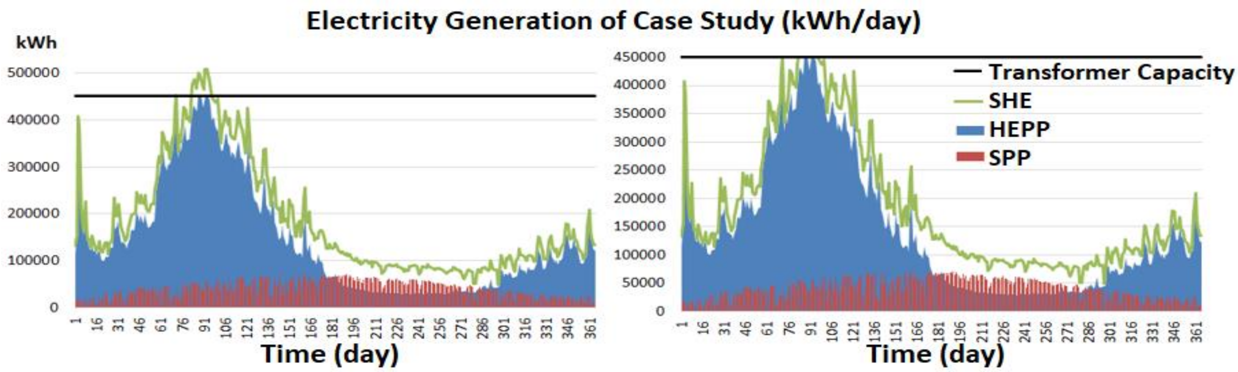

Fig. 9. The electricity generation of the irregular flow based SHE system (1st scenario)

In general, run of river type hydropower has no reservoir capacity. A hydropower plant with water storage/reservoir capacity is chosen for this case study. The present reservoir of the hydropower can work for 3 days within the full capacity mood. So, energy management may be achieved by regulating the flow. During this study, the reservoir effect on the integrated SHE system is demonstrated. The electricity generation of the hydropower is directed to out of daylight period. So, solar energy can generate the most electricity generation within the daylight period. This regulation can provide energy maximization and management for the integrated hybrid system. The reservoir is worked as energy storage during this structure. The benefit/cost optimization indicates that 836. step is that the maximum point of the algorithm for 2nd scenario (regulated/managed flow).

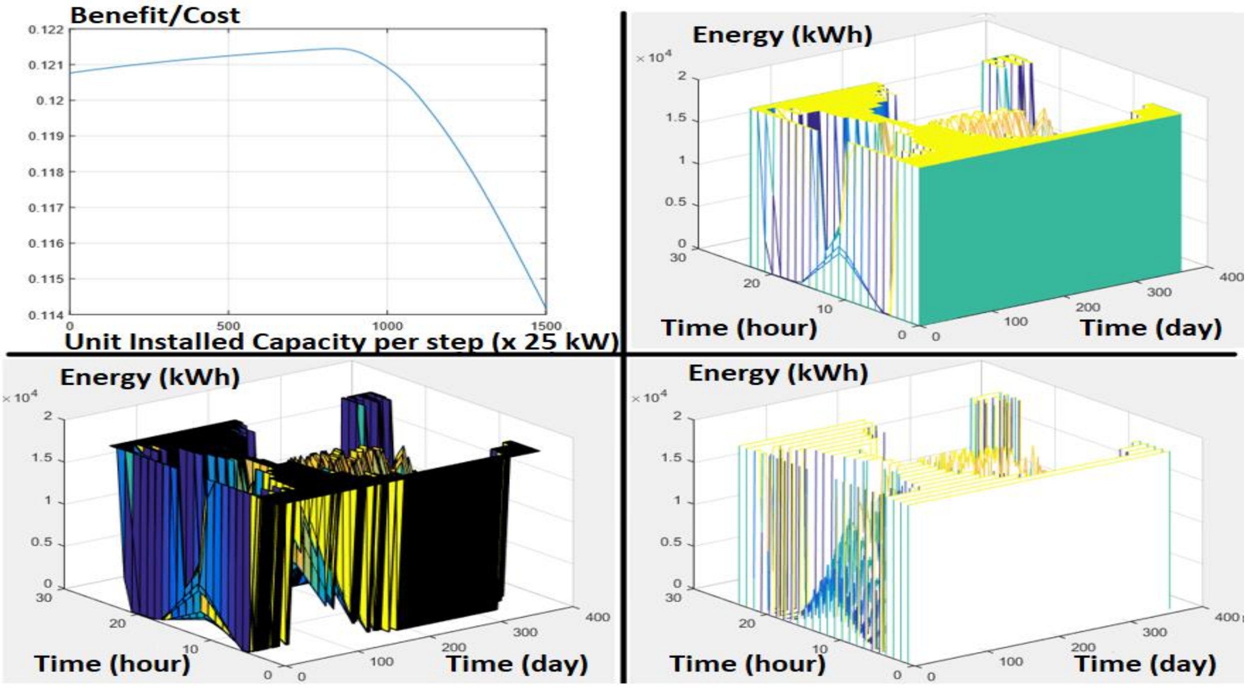

Fig. 10. The optimization of the regulated flows and energy output (2nd scenario)

Regarding the 836. step, 20.9 MW installed capacity solar energy facility is applicable for 18.777 MW installed capacity existing hydropower plant. The overall electricity generation and benefit/cost optimization are given in Figure 10 above. The present hydropower's electricity generation regarding regulated flows, solar energy electricity generation, and total integrated renewable hybrid SHE system's electricity generation is given in Figure 11 below. Solar power can generate 32,571 MWh of electricity. Because of the transformer limitation, 22,359 MWh is available for electricity generation of the integrated renewable hybrid SHE system. The overall electricity generation of the ability is calculated as 75,296 MWh. Due to this integrated renewable hybrid SHE system implementation, the capacity utilization rate of the ability can increase to 46% level.

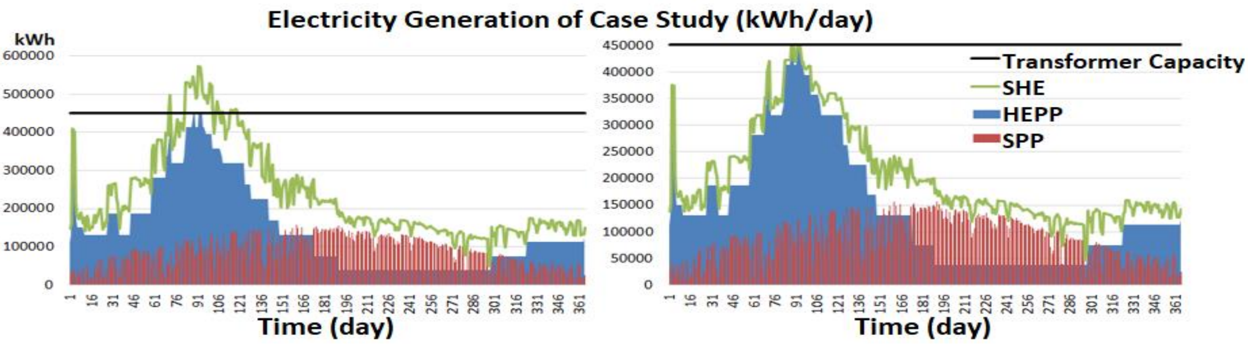

Fig. 11. The electricity generation of the regular flow based SHE system (2nd scenario)

The comparison of scenarios is given in Table 2 below. If the flows are regulated by the system, it's possible to urge more contribution from the integrated renewable hybrid SHE system. It's understood, the reservoir supports the SHE system's installed capacity size, electricity generation, and capacity utilization rate.

Table 2. The comparison of the scenarios

	1st Scenario (Irregular Flows)	2nd Scenario (Regulated Flows)
Installed Capacity	9.575 MW	20.9 MW
Installed Capacity	28.352 MW	39.677 MW
Electricity	67.4 GWh	75.3 GWh
Capacity Factor	41%	46%

4. CONCLUSION

The summarized findings of this study are given in below;

In general, it is a requirement for the quality, stability, and safety of energy transmission lines. Hydro and solar systems are a natural renewable couple for hybrid energy generation. Integrated renewable hybrid SHE systems can provide more energy generation than expected. If a hydropower plant has enough water storage availability, energy management is also provided by an integrated renewable hybrid SHE system. So, it's clear that SHE systems can serve sustainable and stable energy for facilities. Regarding the water storage capacity of the hydropower plant, only solar energy is meaningful for renewable hybrid energy. The solar energy generation period is daylight. So, hydropower energy management is administrated regarding the solar energy generation period. The maximization of energy generation are typically possible. Aside from solar power, other renewable energies don't let to the present energy management, due to their energy generation nature. So, the reservoir effect on the overall energy will be observable for under integrated hybrid SHE systems.

While creating an integrated hybrid energy system, an algorithm was designed to determine the optimum installed power value. This algorithm works on the idea of benefit/cost methodology. The investment cost of the existing hydroelectric power plant and therefore the amount of energy generation is evaluated within the algorithm, taking into consideration the actual values. In solar power, provided by the 2020 IRENA report, the installed power cost per MW has been accepted as 820,000 USD. Because of the loop within the algorithm, the purpose that offers the optimum value has been determined by considering the energy and costs generated in each 25 kW step. In general, solar and hydro energy add harmony with one another, and during this study, the effect of hydroelectric power plants with reservoirs on hybrid structures is shown. For this purpose, two scenarios are considered. Within the first scenario, the hydroelectric station doesn't have a reservoir, so energy is generated without regulating the incoming water flows. During this scenario, it's been calculated that a solar energy plant with an installed power of 9.575 MW may be built on the prevailing facility without a reservoir. Within the second scenario, a case study is performed within which the existing hydroelectric power plant includes a reservoir area, thus regulating the incoming water flows. The water currents are arranged in such a way to maximize the solar electricity generation and to the extent that the hydroelectric plant can manage the incoming currents. As a result of the second scenario, it absolutely was revealed that an extra alternative energy plant with complete installed power of 20.9 MW may well be established. Likewise, within the scene with a reservoir, more energy production and naturally higher capacity utilization rate are possible. Within the first scenario, maximum capacity utilization rates of 41% can be achieved with hybrid energy, while within the second scenario with a reservoir, this rate was 46%. As demonstrated within the case study, regulated flows provide more installed capacity, electricity generation, and capacity utilization.

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DECLARATION OF ETHICAL STANDARDS

The authors of this article declare that the materials and methods used in this study do not require ethical committee permission and/or legal-special permission.

AUTHORS’ CONTRIBUTIONS

Mahir DURSUN: Conceptualization, Methodology, Investigation, Data curation, Visualization, Writing - original draft, Writing - review & editing.

M. Fatih SALTUK: Conceptualization, Methodology, Investigation, Data curation, Visualization, Writing - original draft, Writing - review & editing.

CONFLICT OF INTEREST

There is no conflict of interest in this study.

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