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EFFICIENCY ANALYSIS OF THE SYNCHRONOUS CONDENSER OPERATING MODE IN HYDROELECTRIC POWER PLANTS IN TERMS OF WATER USE

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ABSTRACT

Global climate change and the resulting water scarcity necessitate innovative and efficient approaches in the operation of hydroelectric power plants. Although active electricity generation may come to a halt as water levels drop to critical thresholds during drought periods, the potential of these facilities to contribute to grid stability through the synchronous condenser (SC) mode persists. In this study, the effects of operating the four electricity generation units at the Alpaslan-1 Hydroelectric Power Plant in SC mode on water usage and energy efficiency were analyzed experimentally. During the test process, the units were operated in SC mode for a total of 172 minutes; the facility drew 72 MVAr of reactive power from the grid without performing active electricity generation, thereby providing a total of 52.54 MVArh of reactive energy support to the system. By evaluating the 11-year hydrological data of the plant covering the years 2014-2024, drought periods were determined according to the long-term average, and the strategic advantages of operating the plant in SC mode during these times were demonstrated. According to the findings, a water saving of 575443.2 m³ was achieved in the reservoir thanks to this short-term operation of 172 minutes. It has been calculated that the approximately 115.4 MWh of energy that this saved water would generate if converted to active production would be sufficient to meet the annual electricity needs of 38 households. Furthermore, it was determined that 91.37 MVArh of reactive energy could be provided to the grid for every 1 hm³ of water retained in the reservoir due to the SC mode in drought years. These results demonstrate that hydroelectric power plants, even during periods of water scarcity, can act as strategic "reactive power centers" rather than remaining idle, thereby contributing highly efficiently to grid optimization and long-term sustainable water management.

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1. INTRODUCTION

Rapid growth in the global economy has significantly increased the demand for energy, transforming energy sectors into increasingly resource-intensive structures. This trend has led to serious consequences by generating negative environmental and social impacts [1,2]. Currently, approximately 80% of the global energy demand is still met by fossil fuels. However, these resources not only cause environmental pollution but are also expected to be depleted or become economically difficult to procure by 2050 due to their limited reserves [3]. Therefore, the pursuit of developing unlimited, sustainable, and environmentally friendly new energy sources is gaining increasing importance.

Low-carbon energy sources are rapidly replacing traditional systems based on fossil fuels and crude oil in modern energy production systems [4,5]. As of 2024, the share of low-carbon electricity generation worldwide has exceeded 40% [6]. Increasing global demand for energy resources and environmental concerns have shifted attention increasingly toward renewable energy solutions. This transformation process has significantly accelerated, particularly following China's commitment at the 2015 Paris Climate Conference to increase the share of renewable energy in its total energy production [7]. Among renewable energy sources, hydroelectric energy stands out as one of the most cost-effective and environmentally friendly technologies for electricity generation [8].

In this context, as of 2024, hydroelectric power plants have made a significant contribution to the field of renewable energy by generating approximately 14.3% of the world's total electricity. By 2024, total global hydroelectric installed capacity reached 1.443 GW. Of this, 7.2 GW represents the addition from conventional hydroelectric plants, bringing the total conventional capacity to 1.237 GW. Meanwhile, pumped storage hydroelectric capacity increased by 6.5 GW, reaching 179 GW. In terms of installed capacity, China (421 GW), Brazil (110 GW), the United States (102 GW), Canada (84 GW), and Russia (54 GW) are among the world's largest hydroelectric energy producers. As of 2024, Türkiye ranks first in Europe, alongside Norway, with an installed capacity of 34 GW [9].

Türkiye's current topographic features and rich hydrological conditions offer significant advantages for hydroelectric energy production. In recent years, as is the case globally, the importance of reliable, environmentally friendly, and cost-effective energy sources in meeting rising energy demand has been steadily increasing in Türkiye. As of April 2026, Türkiye’s total installed electricity capacity reached 125.078 MW, with 59.4% of this capacity coming from renewable energy sources such as hydroelectric, solar, and wind power (Table 1). When analyzed by source, hydroelectric power plants hold the highest installed capacity at 32.334 MWe (25.85%). Hydroelectric power plants continue to play a significant role in the electricity system, accounting for approximately one-fourth of the total installed capacity. Hydropower is followed by solar energy with an installed capacity of 26.478 MWe (21.17%) and natural gas power plants with an installed capacity of 24.808 MWe (19.84%) [10].

Table 1. *Türkiye's Installed Capacity by Energy Source (April 2026) (MWe) [10].*

Energy Source	Installed Capacity by Source (MWe)	Percentage %
Hydroelectric	32.334	25.85
Natural Gas	24.808	19.84
Solar	26.478	21.17
Wind	15.039	12.02
Domestic Coal	11.565	9.25
Imported Coal	10.456	8.36
Other	4.398	3.52
Total	125.078	100.00

Hydroelectric power plants are facilities that stand out not only for their electricity generation capabilities but also for their ability to be operated in SC mode. This operational mode contributes to regulating voltage levels in the power grid and maintaining system stability through reactive power generation or absorption [11]. A deficiency or excess in reactive power supply can destabilize the power system, thereby adversely affecting its stability, reliability, and efficiency [12,13]. One of the contemporary methods employed to meet the reactive power demand of the grid is to operate synchronous generators, originally designed for active power generation, in motor mode; this regime is referred to as SC operation [14,15]. SC mode is a specific operating regime in hydropower plants where the turbine-generator unit functions without active power generation, serving solely for reactive

power control and voltage regulation. Under these operating conditions, the generator exhibits synchronous machine characteristics, enabling it to provide reactive power support to the grid and contribute crucial inertia to system frequency stability. Today, driven particularly by the increasing penetration of variable renewable energy sources, the demand for grid flexibility has gained significant momentum. In this context, SC mode emerges as a strategic operational alternative for hydroelectric power plants.

When hydraulic turbines, particularly Francis turbines, are operated in SC mode, the runners rotate in air, unaffected by the water. The air does not drive the runner; rather, it depresses the water level to separate the runner from the water, thereby minimizing friction-related energy losses [16]. This transition is typically performed without shutting down the machine; the unit switches from electricity generation mode (generator mode) to SC mode within a short period. In this state, while the runner rotates in air, the generator provides reactive power support to the grid. In normal production mode, the generator rotates as the turbine runner is driven by water flow; however, in SC mode, the turbine's hydraulic input is deactivated, and the generator functions solely as a SC providing reactive power to the grid. In this configuration, the synchronous generator operates like a motor; rather than producing mechanical energy, it consumes electrical energy from the grid to rotate its rotor.

To achieve this condition, the main inlet valve and guide vanes of the turbine are closed. Subsequently, compressed air is injected into the turbine runner via the draft tube, creating a free water surface within the draft tube. As the turbine runner blades rotate in air, friction with the air generates heat; this process can cause the turbine runner temperature to rise, potentially leading to material deformation. Therefore, it is critical to implement an effective cooling arrangement for turbines operating in SC mode [17].

There are various studies in the literature concerning the electromechanical and operational dynamics of the SC mode.

Kumar et al. emphasize that SC mode enhances the availability period and overall efficiency of hydroelectric power plants. Furthermore, it has been observed that in radial reaction machines such as Francis turbines, air friction generated by the runner rotating in air during SC mode leads to temperature increases in both turbine blades and bearings. This condition necessitates the integration of an effective cooling system capable of spraying water onto the runner blades to ensure safe machine operation. On the other hand, Valentín et al. investigated, through experimental studies on a large-scale Francis turbine prototype, the effects of rapid transitions between active power generation mode and SC mode, and vice versa, on stress fatigue in the turbine runner and machine vibrations. The results of the study indicate that the transition from active generation to SC mode, in particular, represents the most demanding transient regime for the machine and the phase associated with the highest potential for mechanical damage [17,18]. The economic dimension of the SC mode in restructured electricity markets constitutes another fundamental subject of focus among researchers. Vaidya et al. proposed a fair pricing framework for the reactive power provided by hydroelectric power plants in SC mode, basing this structure on key components such as capital expenditure, transition costs between modes (including discharged water losses and mechanical wear), and the duration of stay in condenser mode. Such models support the transition of reactive power support from a free ancillary service to a priced, commercial, and planned service within the grid [19]. In their study, Igbinovia et al. investigated the cost-effectiveness and reactive power generation potential of synchronous condensers. Analyses conducted in the MATLAB/Simulink environment demonstrated that synchronous condensers offer a more economical solution compared to alternative reactive power sources and provide effective reactive power support in medium-voltage grids [20]. In recent years, the environmental impacts of the SC mode on river ecosystems have also begun to be examined in detail in the literature. In a recent field study by Li et al., it was determined that the pressurized air used to dry the turbine in SC mode, combined with the prolonged water-air contact time, can increase total dissolved gas (TDG) supersaturation in rivers to levels as high as 146%. It has been established that this level of supersaturation could pose potential biological risks to aquatic ecosystems, particularly to fish, such as gas bubble disease [21]. In addition to these electromechanical, economic, and environmental evaluations, the strategic importance of the SC mode under hydrological constraints has also come under discussion. It has been stated that during periods of drought or low flow—where water levels decline—the SC mode reduces operational costs and enhances plant availability by preventing frequent start-stop cycles of the machinery [22].

A general review of the literature reveals that research has primarily focused on grid stability, electromechanical fatigue, pricing algorithms, and environmental impacts. However, in an era where climate change and water scarcity conditions are becoming increasingly severe, specific studies that experimentally quantify the direct contribution of the synchronous condensing mode to water conservation and calculate the energy equivalent of the preserved water volume using multi-year hydrological data remain extremely limited. By addressing this literature gap, this study considers the synchronous condensing mode not merely as an electrical grid support tool but also as a strategic water management optimization instrument for drought periods, aiming to provide an original and practical contribution to the field.

2. MATERIALS AND METHODS

In this study, the four power generation units located at the Alpaslan-1 Dam and Hydroelectric Power Plant were operated and tested in synchronous-compensated mode for the first time, and the effects on system performance were analyzed. The study experimentally examined the operating parameters arising during the units' operation in synchronous-compensated mode. The results obtained are presented. The experimental studies were carried out between February 16, 2021, and March 17, 2021.

2.1. Alpaslan-1 Dam

In this study, the four power generation units located at the Alpaslan-1 Dam and Hydroelectric Power Plant were operated and tested in synchronous-compensated mode for the first time, and the effects on system performance were analyzed. The study experimentally examined the operating parameters arising during the units' operation in synchronous-compensated mode. The results obtained are presented. The experimental studies were carried out between February 16, 2021, and March 17, 2021.



Figure 1. *General view of the Alpaslan-1 Hydroelectric Power Plant [23].*

The units at the Alpaslan-1 Hydroelectric Power Plant are operated within a three-stage operating procedure. In the first stage, the turbines are brought into service in "turbine operation" (no-load operation) mode. At this stage, the system is in a pre-generation condition, and the turbines are operated without carrying any load. In the second stage, the units are switched to "line operation" (power generation) mode, in which active electrical energy production is carried out. In this mode, the turbines operate under load and supply energy to the grid. In the third stage, following the closure of the main inlet valve and guide vanes, the units are operated in "condenser operation" (SC mode). In this operating mode, the turbines run without producing mechanical power and contribute to maintaining the reactive power balance of the system [23].

2.2. SCADA (Supervisory Control and Data Acquisition) System

As part of the experiments conducted whilst the turbine-generator unit at the Alpaslan-1 Dam and Hydroelectric Power Plant was operating in SC mode, operational parameters such as reactive power, frequency, power factor, compressor operating pressure, the positions of the main inlet valve and guide vanes, turbine speed, flow rates, air level in the suction pipe, and mechanical losses were measured at regular intervals. The monitoring of these parameters was carried out via the SCADA (Supervisory Control and Data Acquisition) system used within the power plant; this system transmits measurement signals obtained from the plant's equipment to the central control system, enabling real-time monitoring and data logging. Thanks to the SCADA system, the operating parameters of the turbine, generator, and auxiliary equipment were continuously monitored and

recorded. Measurements were retrieved from the database at specified time intervals and analyzed; the data obtained were evaluated in terms of energy efficiency and operational losses, and the effects of operating in SC mode on energy efficiency were demonstrated using statistical methods. Figure 2 presents the operational parameters displayed on the SCADA system screen of the Alpaslan-1 Hydroelectric Power Plant.

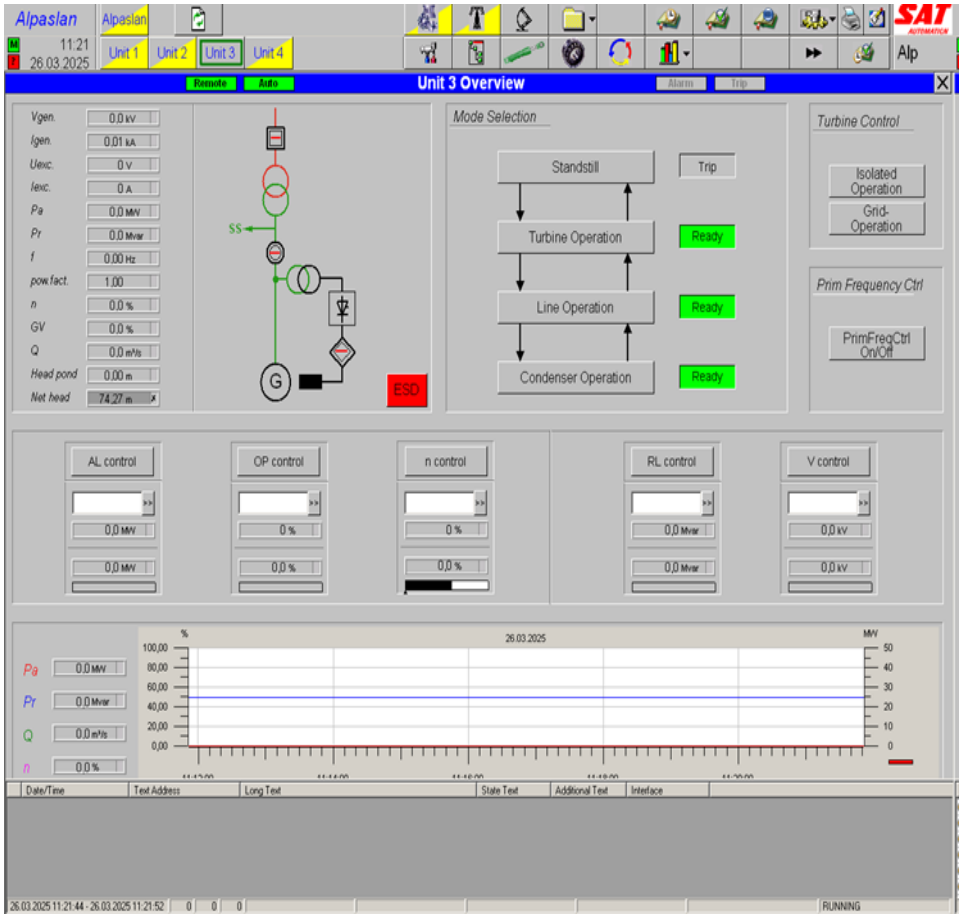


Figure 2. *General operating steps of the Alpaslan-1 Hydroelectric Power Plant [22].*

2.3. Method

In this study, the operational parameters arising during the operation of a hydroelectric power plant unit in SC mode were investigated. Within the scope of the experimental analysis, values were calculated using data obtained from the SCADA system. The equations used in the calculations are presented below.

The amount of reactive power generated when the units are operated in SC mode for a specific period of time was calculated using Equation 1 [24];

$$E_Q = Q_t \times t(s) \tag{1}$$

In this equation, Qt and t(s) represent reactive power support (MVAr) and time (min), respectively. On the other hand, the SC gain is defined as the ratio of the total amount of reactive energy provided in SC mode to the total volume of water used. This parameter has been used to evaluate the grid support performance provided by the system in relation to its water usage. This relationship is expressed as shown in Equation 2 [25].

$$SC_{gain} = \frac{E_{Qtotal}}{V_{Water\ total}} \tag{2}$$

Here, Vwater total (hm^3) denotes the total volume of water utilized. The SC gain (MVArh/hm^3) parameter is used to quantify the reactive power support provided per unit volume of water consumed while the hydroelectric power plant operates in SC mode.

The electrical energy that could be obtained if the volume of water conserved in SC mode were used for active generation has been calculated using the potential energy conversion relationship commonly used in hydroelectric power plants, and this relationship is given in Equation 3 [26].

$$E = \rho \times g \times H \times V \times \eta \quad \textbf{(3)}$$

In this equation, the density of water is denoted by ρ (kg/m³), the acceleration due to gravity by g (m/s²), the head by H (m), the volume of water retained by V (m³), and the overall efficiency by η.

Drought, fluctuations in water levels, and the effects of climate change create significant uncertainties regarding the sustainability of hydroelectric power generation. In this context, reservoir water data for the period 2014–2024 has been evaluated, taking into account the long-term average. In the classification based on annual total water volume, years falling below 75% of the long-term average are defined as dry years, those falling within the 75–125% range as normal years, and those exceeding 125% as wet years [26]. The data relating to this classification are presented in Table 2.

Table 2. *Long-term average water volume (Vavg).*

Year Type	Definition	Numerical Criterion
Dry Year	Significantly below average	V <0.75Vavg
Normal Year	Close to average	0.75 Vavg ≤ V ≤ 1.25Vavg
Wet Year	Significantly above average	V> 1.25 Vavg

In electrical power systems, reactive power compensation capacity is generally classified into small, medium and large-scale systems, depending on the MVAr level. This classification is presented in Table 3.

Table 3. *Classification of reactive power compensation capacities.*

Year Type	Definition	Numerical Criterion
Dry Year	Significantly below average	V <0.75Vavg
Normal Year	Close to average	0.75 Vavg ≤ V ≤ 1.25Vavg
Wet Year	Significantly above average	V> 1.25 Vavg

As shown in Table 3, reactive power compensation capacity varies depending on the system scale. Small-scale systems typically range from 1 to 20 MVAr and are mostly used in industrial facilities at the distribution level or in small substations. Medium-scale systems range from approximately 20 to 100 MVAr and are used in regional substations and medium-sized generation facilities to ensure voltage control and reactive power balance. Large-scale systems, on the other hand, generally have capacities of 100 MVAr and above and play a significant role in stabilizing system voltage in high-voltage transmission networks and ensuring the operational safety of large-scale power systems [27].

3. RESULTS AND DISCUSSION

The four units at the Alpaslan-1 Hydroelectric Power Plant were tested sequentially in synchronous condensing mode. During the analysis, it was recorded that the units were operated in SC mode for a total of 172 minutes, with Unit 1, Unit 3, and Unit 4 operating for 50 minutes each, and Unit 2 for 22 minutes. The recorded durations are presented in Table 4.

Table 4. *Classification of reactive power compensation capacities.*

Unit No	Operating Time (min)	Reactive Power Support (MVAr) Q_t
Unit-1	50	-20
Unit-2	22	-16
Unit-3	50	-20
Unit-4	50	-16
Total	172	-72

A negative Qt value indicates that reactive power is being drawn from the system. During the period in question, the power plant drew 72 MVAr of reactive power from the grid without generating active power, thereby supporting the system's voltage regulation. The variations in the reactive power drawn from the electricity grid are due to the units being tested at different times. On the days the tests were conducted, variations in the power plant's operating conditions and the grid's reactive power requirements—in accordance with the operating instructions determined by the production planning unit—led to differences in the reactive power drawn from the grid.

Taking into account the operating times of the units, the reactive power was calculated using Equation 1. Figure 3 shows the reactive power corresponding to each unit.

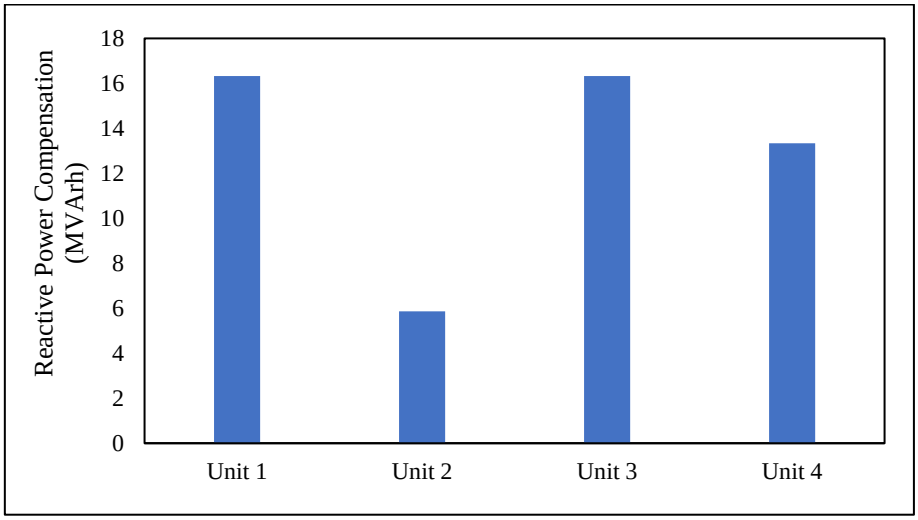


***Figure 3**. Reactive power equivalent, taking into account the operating time of the units.*

The calculations revealed that, over a 50-minute operating period, Units 1 and 3 generated the highest reactive energy values, at approximately 16.33 MVArh. In contrast, it was observed that Unit 4 provided a lower reactive energy value of approximately 13.33 MVArh during the same period. Furthermore, it was determined that during a 22-minute operating period, Unit 2 had the lowest reactive energy value of approximately 5.87 MVArh compared to the other units. The primary reason for the difference in reactive energy values between the units is that each unit was operated in SC mode for different durations, and the grid's reactive power requirement varied during the time periods in which the tests were conducted. In particular, the fact that Unit 2 was operated in SC mode for a shorter duration led to the reactive energy value obtained being lower than that of the other units. Conversely, the longer operation of Units 1, 3 and 4 contributed to a higher amount of reactive energy being supplied. As a result of the units being operated in SC mode for 172 minutes, a total of 52.54 MVArh of reactive energy was supplied by the power plant. This figure demonstrates that the power plant possesses a high reactive support capacity even during short-term operation.

Figure 4 shows the total water volumes entering the reservoir of the Alpaslan-1 Hydroelectric Power Plant between 2014 and 2024, as well as the average annual water volume values. Based on the average values shown in the graph, the years have been classified as dry, normal and wet.

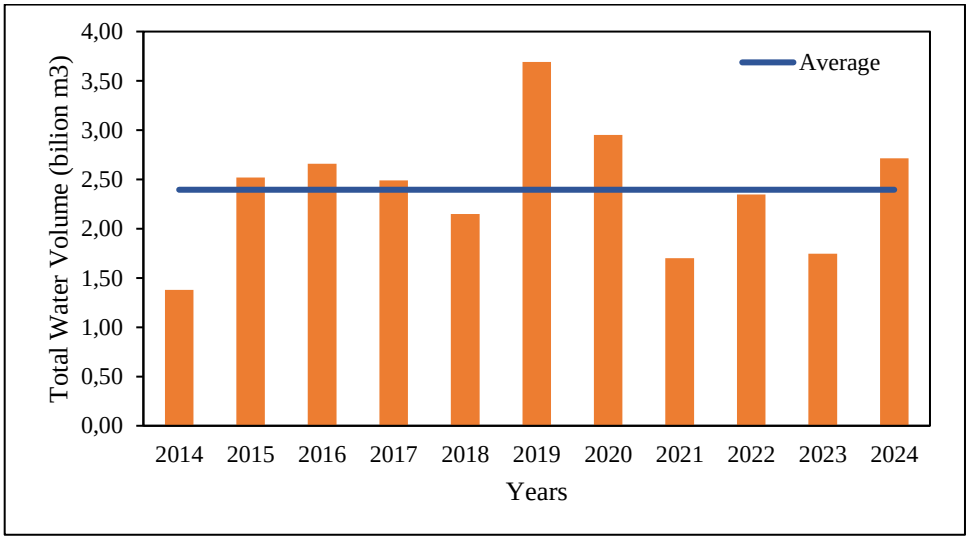


***Figure 4.** Annual total water inflow volumes to the Alpaslan-1 Hydroelectric Power Plant reservoir for the period 2014–2024.*

The data obtained were evaluated based on the long-term average water volume V_{avg} classification given in Table 1. Accordingly, the years 2014, 2021, and 2023 were classified as dry years because the volume of water entering the reservoir remained below the 0.75 Vavg value. In particular, it is observed that the total water volume entering the reservoir in 2019 exceeded the 1.25 V_{avg} value. Consequently, 2019 has been classified as a wet year. In contrast, it was determined that in 2015, 2016, 2017, 2018, 2020, 2022, and 2024, the volume of water entering the reservoir remained within the range of 0.75 to 1.25 V_{avg}, and consequently, these years were assessed as falling within the normal year category. These results demonstrate that the volume of water entering the reservoir varied significantly from year to year throughout the period under review and that hydrological conditions have a significant impact on the operational performance of the hydroelectric power plant.

During the periods classified as dry years (2014, 2021, and 2023), the average inflow rate to the Alpaslan-1 Dam and Hydroelectric Power Plant reservoir was measured at 55.76 m³/s, based on data obtained from water level sensors via the SCADA system. Considering this value, it was calculated that approximately 575443.2 m³ (0.575 hm^3) of water could be retained in the reservoir for the conditions in which the units were operated in synchronous condensing mode for a total of 172 minutes. It was determined that the synchronous condensing mode enables the preservation of tens of thousands of cubic meters of water in reserve while simultaneously providing significant reactive power support.

The gain for the SC mode during dry years was calculated using Equation 2.

$$SC_{gain} = \frac{52.54}{0.575} = 91.37\ MVArh/hm3)$$

This value was obtained by dividing the total amount of reactive energy provided in SC mode by the total volume of water conserved during the same process. The results show that, in dry years, approximately 91.37 MVArh of reactive energy can be provided while conserving every 1 hm³ of water, thanks to units operated in SC mode. In this context, while 1 hm³ of water volume corresponds to only a few hours of active power generation during dry years, the same volume of water can be used to provide long-term reactive power support to the grid. This clearly demonstrates that SC mode is a strategic operational tool, particularly during dry years, for both the conservation of water resources and the provision of grid support services.

The amount of electrical energy that could be generated by utilizing the volume of water conserved through operation in SC mode has been calculated using Equation 3.

$$E = 1000(kg/m^3) \times 9.81(m/s^2) \times 80.2(m) \times 575443.2(m^3) \times 0.9172$$

$$E \cong 4.14 \times 10^{11} J \ \cong 115.4\ MWh$$

It has been calculated that the 575443.2 m³ of water volume conserved through the SC mode would correspond to the generation of approximately 115.4 MWh of electrical energy if utilized for active generation, taking into account the power plant's 80.2 m net head and 91.72% overall efficiency [28]. The calculated 115.4 MWh of active production-equivalent energy represents a significant amount when considering the average residential electricity consumption in Türkiye. Assuming an annual electricity consumption of 3000 kWh per household [29], it is evident that this amount of energy is sufficient to meet the annual electricity needs of approximately 38 households.

The findings indicate that the SC mode is not merely an auxiliary operating mode, but also a strategic tool in terms of multi-year water management and grid optimization. During periods of water scarcity, even when active generation is not possible, the power plant can continue to provide reactive power support and preserve reserve water for future periods. The reactive power of 72 MVAr is sufficient to meet the reactive power requirements of a medium-sized substation on its own [30]. Furthermore, when analyzed in conjunction with 11 years of water data, it can be said that the SC mode increases operational flexibility during dry months and enables the power plant to function as a 'reactive power center' for the grid.

4. CONCLUSIONS

As Türkiye is located in the Mediterranean belt, which is expected to be severely affected by climate change, this necessitates innovative optimizations in the operation of hydroelectric power stations that are adapted to climatic conditions. This study highlights the strategic importance and efficiency of operating hydroelectric power stations not only for active energy generation but also to provide reactive power support to the grid in SC mode, given the current conditions where water uncertainties linked to climate change are increasing. The key

findings and sectoral recommendations derived from analyses and experimental studies conducted using data from the Alpaslan-1 Hydroelectric Power Plant are summarized below:

- Over the 11-year period from 2014 to 2024, the long-term average water volume was measured at approximately 2.395 billion m³. It was found that 27% of this period was dry, 64% was normal and 9% was wet; in dry years, the total water volume was found to be 25–40% below the average.
- During dry years and periods of low flow, consideration should be given to operating hydroelectric power stations in SC mode rather than taking them completely offline. This approach will help to conserve water resources whilst also improving grid voltage stability.
- Despite the curtailment of conventional generation during dry years, the units were operated in SC mode for a total of 172 minutes, thereby supplying 52.54 MVArh of reactive power to the grid without consuming water or generating active power.
- Thanks to the short-term operation of the SC mode, a water volume of 575443.2 m³ has been maintained in the reservoir. It has been calculated that the approximately 115.4 MWh of energy this water would generate if converted into active production is equivalent to the annual electricity requirements of 38 households.
- It has been calculated that, particularly in dry years, operating the units in SC mode enables 91.37 MVArh of reactive power to be supplied to the grid for every 1 hm³ of water retained in the reservoir.

5. RECOMMENDATIONS AND FUTURE OUTLOOK

- Dry Season Operation Strategy: During dry periods when water levels fall, hydroelectric power stations should not be left completely idle; instead, they should be operated in SC mode to both conserve water resources and support the voltage stability of the grid.
- Role for Grid Operators: Grid operators should view hydroelectric power stations not merely as generation facilities, but as regional reactive power support points, and should plan transmission line voltage regulation during dry years via these stations.
- Integration into Strategic Planning: New hydro-electric indicators, such as the reactive power-to-water savings ratio, should be formally integrated into national water management and grid operation strategies.

In future research, the effects of the SC mode on long-term operating scenarios, mechanical losses, torque fluctuations and auxiliary systems (cooling, etc.) should be investigated. Furthermore, to demonstrate the generalizability of this approach, comparative analyses should be carried out on power stations with different types of hydraulic turbines and at different installed capacity levels.

Conflict of Interest

There is no conflict of interest between the authors.

Authors Contributions

Murat Bahar: Conceptualization, Methodology, Software, Validation, Formal Analysis, Investigation, Resources.

Zeki Argunhan: Conceptualization, Methodology, Validation, Formal Analysis, Investigation, Supervision, Project Administration.

Emin El: Formal Analysis, Data Curation, Writing—Original Draft, Writing—Review & Editing, Visualization, Supervision.

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Statement of Research and Publication Ethics

The authors declare that this study complies with research and publication ethics. This study does not require an ethics committee approval as it does not involve any human or animal subjects, surveys, or clinical data.

Artificial Intelligence (AI) Contribution Statement

During the preparation of this manuscript, the authors only used AI programs to improve readability and language. After using this tool or service, the authors reviewed the content and edited it as necessary.

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