Thermodynamic Cycle and Energy Transfer Fundamentals by a P&ID principle diagram for "Salt Caves" (Salt Domes) in Iğdır, Tuzluca province to be used as an "Energy Storage System"

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Abstract

The salt caves in Iğdır province provide extensive benefits for health purposes in addition to their tourism use, and the Iğdır University Salt Therapy Center in Tuzluca district provides important services to human health. These salt caves in Iğdır can serve as an "Energy Storage System" for industrial purposes, in addition to their tourism and health uses.

In this article, entitled as “Thermodynamic Cycle and Energy Transfer Fundamentals by a P&ID principle diagram for "Salt Caves" (Salt Domes) in Iğdır, Tuzluca province to be used as an "Energy Storage System"; scientific and technical information is given about the project that allows the "Salt Caves" (Salt Domes) in our Iğdır, Tuzluca province to be used as an "Energy Storage System" in addition to their current usage purposes.

While a compressor-driven gas turbine system can only transfer about one-third of the generated electrical energy to the grid, it is evident that if the gas turbine is connected to a Compressed

Air Energy Storage (CAES) system, all the generated electrical energy can be transferred to the grid, achieving a very high system efficiency. In a gas turbine system, when electrical energy is conventionally produced, 2/3 of the generated energy is used to compress the air in the turbine compressor. If a CAES system is implemented and salt caverns are used as an energy storage facility, almost all of the generated energy can be fed into the grid as useful electrical energy.

The salt domes (salt caves) in Iğdır province of Turkey provide extensive benefits for health purposes as well as being used for tourism purposes, and provide important services to human health by means of the Iğdır University Salt Therapy Center located in Tuzluca district. These salt domes in Iğdır can serve as an "Energy Storage System" for industrial purposes as well as being used for tourism and health purposes. The name of the energy production system described in this article is “Compressed Air Energy Storage System (CAES)” and it is usually operated combined with a gas turbine system. [7], [8], [9], [16]

Keywords: CAES – Compressed Air Energy Storage Systems, Salt Dome, Salt Cave, Cogeneration, Gas Turbine, Energy Efficiency, Energy Transfer, Electrical Energy, Heat Energy, Thermodynamics, Fluid Mechanics, Energy Production Systems, Compressor, Natural Gas, Energy Storage System, Adiabatic Process.

Introduction

This article entitled as “Thermodynamic Cycle and Energy Transfer Fundamentals by a P&ID principle diagram for "Salt Caves" (Salt Domes) in Iğdır, Tuzluca province to be used as an "Energy Storage System"; provides scientific and technical information about the project that allows the "Salt Caves" in Iğdır province to be evaluated as an "Energy Storage System" in addition to their current uses. The salt caves in Iğdır province provide extensive benefits for health purposes in addition to their tourism use, and the Iğdır University Salt Therapy Center in Tuzluca district provides important services to human health. These salt caves in Iğdır can serve as an "Energy Storage System" for industrial purposes, in addition to their tourism and health uses. [7], [8], [9], [16]

Method, Findings and Discussion

The energy production system described in this study is called a "Compressed Air Energy Storage System (CAES)" and is usually operated in conjunction with a gas turbine system. [10], [11]

Without CAES, the generator can transfer approximately 1/3 of its available power to the grid (33%). The remaining 2/3 (66%) is used to compress the air pressurized for the combustion process in the combustion chamber of the gas turbine. If CAES, i.e., Compressed Air Energy Storage Systems, are used, the compressed combustion air is sent separately to the turbine, and thus the generator can transfer all the power it produces to the electricity grid. To recharge the CAES system, the compressor is operated using electricity from the grid during times when the demand for electrical energy is low.

For the establishment of such an energy production system and facility using natural gas fuel, an energy storage facility is required, and the salt caves in our Iğdır province can be used as energy storage caves. There are examples of this system currently operating in the world. A portion of the existing salt caves in our Iğdır province can be used as energy storage caves to function as an energy storage system and contribute to the industry and economy of our region and country. The P&ID principle diagram showing the thermodynamic cycle and energy transfer fundamentals of the natural gas-fueled electricity generation using a Compressed Air Energy Storage System (CAES) with salt caves is given in Figure 1, and the general operation of the system is shown in this diagram.

Scientific and technical studies can be started immediately to establish such an electricity generation plant by using the aforementioned salt caves for energy storage purposes. The necessary potential for the establishment of the system exists in the Tuzluca region. It will also be possible to further increase the efficiency by combining the planned facility with a cogeneration type energy production system. [1], [2], [3], [4], [5], [6], [7], [8], [9], [10], [11], [12], [13], [14], [15], [16]

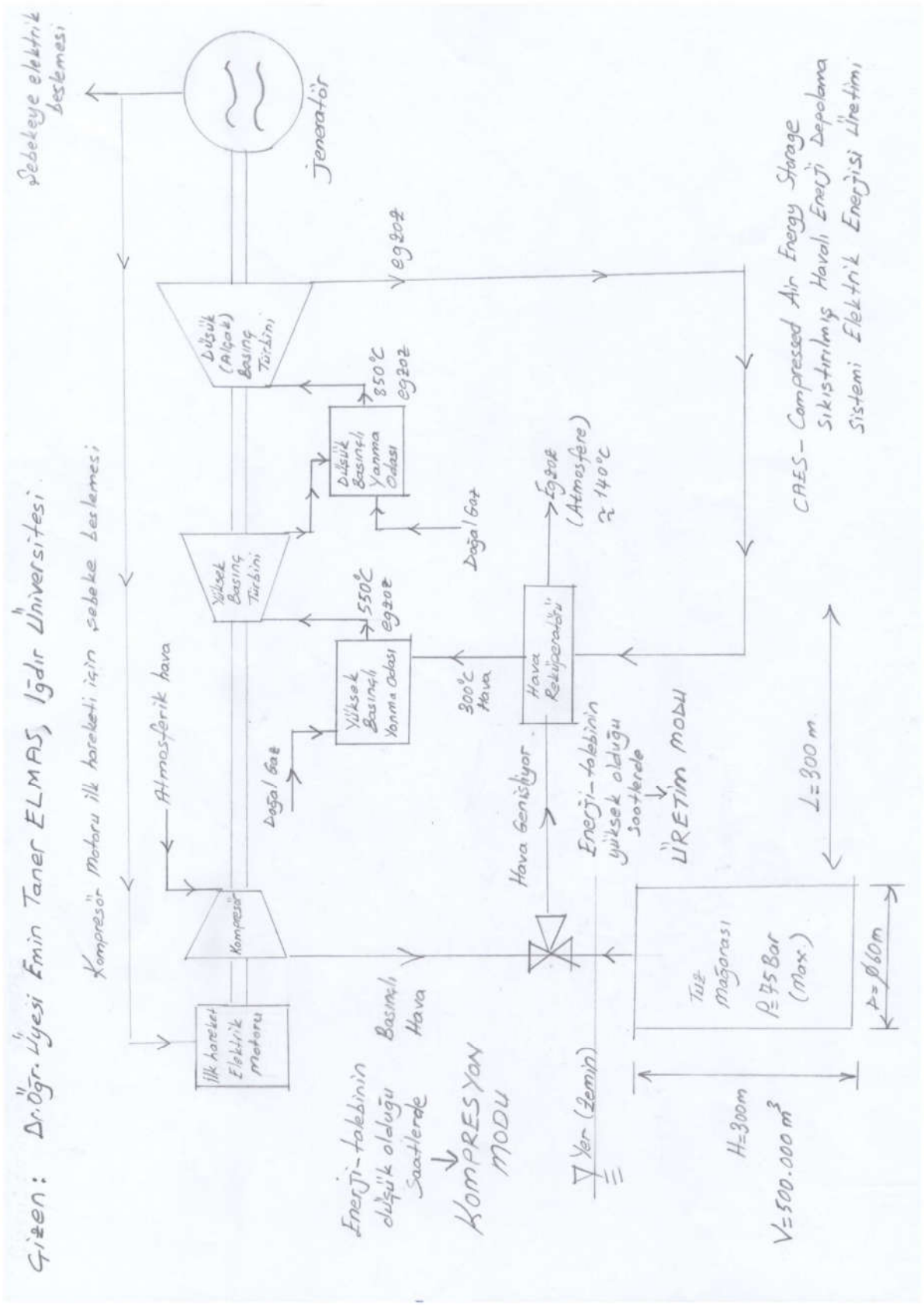

Figure 1: P&ID principle diagram showing the thermodynamic cycle and energy transfer fundamentals of natural gas-fired electricity generation using Salt Caves and CAES - Compressed Air Energy Storage System. [7], [8], [9], [10], [11], [16]

Conclusion

While a compressor-driven gas turbine system can only transfer about one-third of the generated electrical energy to the grid, it is evident that if the gas turbine is connected to a Compressed Air Energy Storage (CAES) system, all the generated electrical energy can be transferred to the grid, achieving a very high system efficiency. In a gas turbine system, when electrical energy is conventionally produced, 2/3 of the generated energy is used to compress the air in the turbine compressor. If a CAES system is implemented and salt caverns are used as an energy storage facility, almost all of the generated energy can be fed into the grid as useful electrical energy.[1], [2], [3], [4], [5], [6], [7], [8], [9], [10], [11], [12], [13], [14], [15], [16], [17], [18], [19], [20], [21], [22], [23], [24], [25], [26], [27], [28], [29], [30], [31], [32], [33], [34], [35], [36], [37]

Adiabatic systems can achieve higher efficiency values than non-adiabatic systems. [7], [8],[9],[10],[11], [16] The use of salt caves as an “Energy Storage System” will provide great scientific, technical and economic benefits for our Iğdır province and our region in general, and will also make extremely important contributions to our country’s “Domestic and National Energy Production” goals. [7], [8], [9], [16]

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Asst.Prof. Dr. Emin Taner ELMAS is a Mechanical Engineer having degrees of B.Sc., M.Sc., Ph.D., and was born in Sivas in 1974. He completed his doctorate at Ege University, Graduate School of Natural and Applied Sciences, Mechanical Engineering Department, Thermodynamics Science Branch, and his master's degree at Dokuz Eylül University, Mechanical Engineering Department, Energy Science Branch. He also completed his undergraduate education at Hacettepe University, ZEF, Mechanical Engineering Department and graduated from the faculty with honors in 1995 and became a mechanical engineer. He was awarded a non-refundable scholarship by the Turkish Chamber of Mechanical Engineers in his 4^{th} year because he was the most succesful student during his first 3 classes study at the faculty. He graduated from İzmir Atatürk High School in 1991.

Asst. Prof. Dr. ELMAS has completed his military service as a NATO Officer in Bosnia and Herzegovina. He was a “Reserved Officer” as a “2^{nd} Lieutenant” as an “English-Turkish Interpreter”. He was also a “Guard Commander” and served in Sarajevo, Camp Butmir within the SFOR task force of NATO. He has been awarded with 2 (two) NATO Medals and Turkish Armed Forces Service Certificate of Pride (Bosnia & Herzegovina).

In addition to his academic duties at universities, he has worked as an engineer and manager in various industrial institutions, organizations and companies; He has served as Construction Site Manager, Project Manager, Management Representative, Quality Manager, Production Manager, Energy Manager, CSO-CTO, CBDO, Factory Manager, Deputy General Manager and General Manager.

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Asst. Prof. Dr. Emin Taner ELMAS is also an accomplished musician, specializing as a virtuoso on the saz (baglama) and as a performer of the ney (Turkish reed flute). He maintains a YouTube music channel under his name, featuring recordings of his performances on both instruments. In tribute to his father, Judge Raşit ELMAS, he composed the poem by the renowned poet Âşık Veysel ŞATIROĞLU, titled *“Raşit Bey”*, as *“Raşit Bey Türküsü”*, and subsequently transcribed, notated, and published it as an academic article, sharing the composition on his music channel.

Additionally, he authored the poems *“Canım Babam”* and *“Geldim Babam”*, also in memory of his father, publishing them in an academic literature journal and composing instrumental music for both pieces. In honor of his mother, Lawyer Tuna ELMAS, he composed an instrumental piece titled *“Annem Annem Türküsü”*, which he gifted on Mother’s Day, May 11, 2025. His creative output further includes the poem *“Ney and Neyzen”* and the piece *“Esra Kardeşim”*, dedicated to his sister, Esra ELMAS, an archaeologist and English teacher.

He has authored several books on music, including *Saz-Bağlama Tuning System Method* (*Saz-Bağlama Akort Sistemi Metodu*) and *Ney and Neyzen: Ney’s Pitches, Frets, Sound Stages, Octaves, Structure, Performance, Maintenance, and Basic Music Theory* (*Ney ve Neyzen: Ney’de Perdeler, Ses Devreleri, Oktavlar, Yapısı, İcrası, Ney Bakımı ve Temel Musiki Nazariyatı*). He continues to pursue his artistic endeavors through the composition of music, the creation of repertoires, and the publication of articles, books, poetry, and lyrics.

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