



School of Information Technology and
Engineering at the ADA University



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INNOVATIVE METHODS AND TECHNOLOGIES TO INCREASE THE EFFICIENCY
OF THE ENERGY SYSTEM

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By
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THESIS ACCEPTANCE

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has been approved as meeting the requirement for the Degree of Master of Science in Electrical and Power Engineering of the School of Information Technology and Engineering, ADA University.

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ABSTRACT

The fundamental mission of the energy system is to consistently provide the required electricity to all segments of the network, while keeping to accepted economic and quality norms. Transmission lines play a crucial role in facilitating the transportation of electrical power from generation stations to end consumers. The maintenance of transmission lines and generation plants holds significant importance in ensuring power system reliability, minimizing operational costs, and prolonging the lifespan of equipment. In addition, the operation of the system with all available equipment ensures that the system is maintained at the highest degree of security.

Power plants are responsible for the generation of electricity, which is subsequently transmitted and distributed to clients via power lines. High-voltage transmission lines, characterized by their suspension between towering metallic structures, serve the purpose of efficiently transporting power across extensive distances in order to cater to the demands of consumers. The utilization of higher voltage electricity proves to be more efficient and cost-effective for transmitting electricity across vast distances. The utilization of lower voltage power in residential and commercial settings is associated with enhanced safety. Transformers located at substations play a crucial role in the adjustment of voltages during the various stages of electricity transmission. These transformers are responsible for either increasing (step up) or decreasing (step down) voltages to accommodate the diverse requirements encountered during the journey from power plants through long-distance transmission lines to distribution lines, which deliver electricity to residential and commercial establishments.

This thesis introduces an approach for developing optimal strategies to enhance the efficiency of power systems. The topic incorporates network and operational restrictions regarding energy systems that experience seasonal variations in weather conditions, load demands, and generating patterns. Advanced materials and sophisticated procedures are

employed to model and address the issue of efficacy. Moreover, an innovative strategy has been developed as well as implemented to address the significant issue of reducing the excessive time constraints associated with the current methodology.

Both the proposed technique and the present method were utilized in the construction of the model of the Azerbaijan Power Network for the year 2023. The collected results are analyzed by engineers, and the advantages and disadvantages of the traditional and contemporary approaches are highlighted.

This thesis presents a new structure for formulating optimal strategies aimed at improving the efficiency of transmission lines and generating units. The problem considers the constraints imposed by network and operational limitations, specifically in power systems that exhibit seasonal fluctuations in weather conditions, load demand, and generation patterns. The demand for electrical energy is increasing steadily, leading to various challenges within power systems such as power loss, insufficient line capacities, and voltage sag. Fortunately, the utilization of innovative materials and contemporary methodologies is employed to model and address the difficulty of efficiency. In addition, contemporary techniques have been developed and applied in order to mitigate the substantial level of efficiency demanded by the traditional approach to problem-solving.

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LIST OF ABBREVIATIONS

Abbreviation	Explanation
DC	Direct Current
AC	Alternating Current
OSJC	Open Joint – Stock Company
OTL	Overhead Transmission Lines
HVDC	High Voltage Direct Current
HVAC	High Voltage Alternating Current
AAC	All – Aluminium Conductor
AAAC	All Aluminium Alloy Conductor
ACSR	Aluminium Conductor Steel Reinforced
HTLS	High Temperature Low Sag
REN	Regional Electrical Network
HVEN	High Voltage Electrical Network
(Z)TACSR	Thermal Resistant Aluminium Conductor Steel Reinforced
G(Z)TACSR	Gap – Type Aluminium Conductor Steel Reinforced
(Z)TACIR	Aluminium – Clad Invar Core Thermal Resistant Conductor
(Z)TAL	Heat-Resistant Zirconium Aluminum Alloy Wires
TPP	Thermal Power Plant
P	Active Power
Q	Reactive Power
S	Apparent Power
CHP	Combined Heat and Power Plant
IoT	Internet of Things
AMI	Advanced Metering Infrastructure

CHAPTER ONE

INTRODUCTION

1.1. Introduction

The energy system of Azerbaijan can be categorized into three main components: generation, transmission, and distribution. In order to enhance the efficiency of a system through the use of innovative techniques and methods, it is imperative to first have a comprehensive understanding of the existing structure and associated challenges. Based on data provided by the Ministry of Azerbaijan Republic, the total installed power capacity of the country is reported to be 7442.75 MW, encompassing both conventional and renewable energy sources. Both the consistent increase in the world's population and the continual advancement of technology are major factors in the progressive rise in the demand for energy. By the year 2050, the demand for power is expected to have risen by a number of two, according to estimations. As a component of the overall strategic planning, it is anticipated that the level of energy consumption in Azerbaijan will rise by 3.8% over the course of the subsequent ten years. This information comes from the report that was made public by AzerEnerji OSJC.

1.2. Problem Formulation

The purpose of this thesis is to investigate and address the challenges and opportunities in optimizing energy systems, with a focus on enhancing their efficiency, and reliability. Through a comprehensive examination of modern technologies, methods, and strategies. To achieve higher efficiency can be done with economical and practical aspects, this research aims to analyze the current state of energy system, identifying key challenges.

This research project aims to investigate and evaluate innovative concepts and developments in order to offer valuable opinions and suggestions to key participants in the energy sector. These key players include transmission system and generating operators. The

objective is to assist them in making well-informed decisions associated to the improvement of energy system efficiency.

By achieving these objectives, this thesis seeks to contribute to the advancement of energy infrastructure, support sustainable energy practices, and ultimately ensure the reliable and efficient supply of electrical energy to meet the growing demands of the future.

CHAPTER TWO

LITERATURE REVIEW

In Azerbaijan, as well as in many other countries in the world, fossil fuels are an essential raw material today that are used to supply the demand for energy. However, a study that was carried out by a well-known fuel company found that the percentage of renewable energy used in the production of power around the world climbed from 10.3% to 11.7%, while the percentage of coal used in the production of electricity dropped by 1.3 points to 35.1%. In recent years, it would appear that this rate reflects the lowest level that coal's share of the production of power has ever achieved (in terms of percentage). This circumstance demonstrates that renewable energy sources have the potential to offer at least some of the energy supply that will be delivered in the future by fossil fuels. The integration of renewable energy sources into the grid is made more difficult by the fact that these sources are frequently located in remote places and in a dispersed manner, both of which are located a significant distance from the grid connection points. To bring up yet another issue that is connected to fossil fuels, it is inevitable that electric vehicles will eventually take the place of automobiles that are powered by fossil fuels. As a consequence of this, there will be an increased need for energy in the years to come.

There are 1393.55 megawatts (MW) of renewable energy power plants that contribute to this capacity. These power plants, which can include large hydropower projects, account for around 17.4 percent of the total capacity. This highlights that a sizeable amount of the energy mix utilized by the comes from renewable sources. The Thermal Power Plant (TPP) is measured by these criteria, which account for 77.7 percent, which is equivalent to 5782.5 megawatts (MW) [1]. The following table provides an overview of the current installed ratings of power plants in 2023, and the table immediately after it provides further information about these ratings.

**Table 2.1 Installed Capacity of Power Plants Included in the 2023 Scheme of the
Azerbaijan Republic**

Types		MW		Per Cent	
Thermal Power Plant		5782.5		77.7	
Renewable Power Plant	Hydro	1660.25	1293.55	22.31	17.4
	Solar		268		3.6
	Wind		55.3		0.74
	Hybrid		6.4		0.09
	Independent		37		0.5

The quantity of fuel consumed for the purpose of electricity generation is contingent upon the efficiency of the power plant as well as the heat content inherent in the fuel. The heat rate is a metric utilized to assess the efficiency of a generator or power plant, and it quantifies the quantity of energy required to produce one kilowatt of electricity. The efficiency of power plants, also known as heat rates, is conditional upon several aspects including the type of generator, the implementation of emission controls inside the power plant, and various other considerations. The amount of fuel is considered as the main factor to generate 1 kW*hour. After understanding the importance of this parameter, we can apply new methodology to improve efficiency at the generation part. The following table illustrates key data for the main power plants for energy system.

The overhead transmission line (OTL) known as the 500 kV Samukh-Gardabani, which was commissioned as part of the "Azerbaijan-Georgia-Turkey Energy Bridge Project," possesses a transmission capacity of 650 MW. The energy systems of Azerbaijan and Russia are interlinked via two interstate overhead transmission lines (OTLs). The transmission lines in consideration are 330 kV Darbend, which run from the "330 kV/110 kV Xachmaz" substation to the "330 kV/110 kV Darbend" substation. Additionally, there is the 110 kV Yalama line, which links the "110 kV/35 kV Yalama" substation and the "110 kV/35 kV Bilici" substation.

Table 2.2 Production of Electricity at Thermal Power Plants on Average Day

Power Plants	Production of electricity (thousand kW*hour)	Fuel Consumption Gas (thousand m ³ /ton)	Gram per kW*hour
Azerbaijan	7537.72	1951.818	336.17
			331.26
			338.40
Cenub	17324.148	3429.457	228.36
Shimal-1	8558.55	1628.091	220.872
Shimal-2	9365.329	1703.087	212.789
Astara	867.0	167.168	295.73
Lerik	101.2	21.442	289.35
Sheki	783.0	175.240	279.93
Xachmaz	685.0	120.215	282.27
Baku	1582.0	405.624	284.37
Sumgait	10876.672	2188.390	234.11
Sangachal	2619.1	541.111	280.58
Gobu	7447.6	1589.429	262.07
Shahdag	685.1	69.175	280.54
Total	68432.419	13990.247	247.40

There exist two overhead transmission lines connecting the energy systems of Azerbaijan and Georgia. These lines include the 500 kV "Samukh-Gardabani" high-voltage direct current (HVDC) line, which facilitates the export of electricity from Georgia to Turkey through transit, and the 330 kV "Aghstafa-Gardabani" overhead transmission line (OTL). The exchange of electricity between the energy systems of Azerbaijan and Iran is facilitated by a total of five active power transmission lines. These lines consist of the 330 kV "Mugan" line, the 230 kV "Parsabad" line, the 110 kV "Astara-Astara" line, and the 132 kV "Araz-Araz" and 132 kV "Culfa-Culfa" lines. The energy systems of Azerbaijan and Turkey are connected by three overhead power transmission lines, namely "Igdir-Nakhchivan 1" operating at 154 kV, "Igdir-Nakhchivan 2" also operating at 154 kV, and "Sadarak" operating at 34.5 kV [2]. During the span of four years, there has been a notable reduction in the percentage of out-of-date lines, declining from 68.7 percent to 56.6 percent. It is important to note that efforts to address this issue are still in progress.

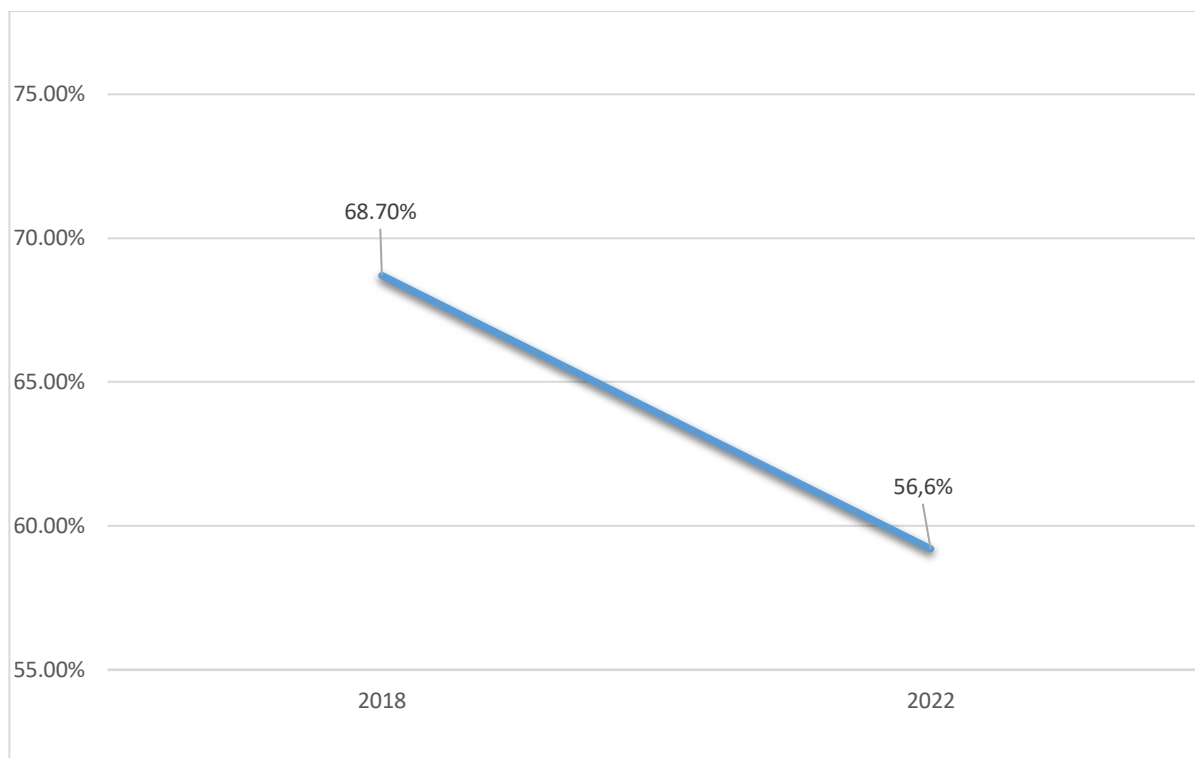


Fig. 2.1 Decrease Observed in the Quantity of Aged Overhead Transmission Lines

In the context of electric transmission lines, many maintenance activities have been performed, including the substitution of porcelain and damaged glass insulators with new glass ones, the repair of damaged line fittings, the welding of supports, applying of paint, the cleaning of tracks, and the trimming of trees. The longitudinal span of OTLs experienced a growth from 7551.74 km to 8589.3 km throughout the period that covers 2018 to 2022.

Table 2.3 The State of Overhead Transmission Lines in 2022

Line Voltage	The Number of OTLs	The Length of OTLs	Out-of-Date Lines and impracticable	
			Length	Percent
500 kV	3	477.44 km	226 km	47.3%
330 kV	27	1 770.0 km	1 107.5 km	62.6%
220 – 230 kV	37	1 804.8 km	688.9 km	38.2%
110 kV	230	4 537.1 km	2 839 km	62.6%
Total	297	8 589.3 km	4 861.4 km	56.6%

The chart shown provides a detailed overview of an electrical transmission system, outlining important information pertaining to different line voltage categories. The analysis

focuses on four voltage levels, namely 500 kV, 330 kV, 220-230 kV, and 110 kV, together with their relevant factors. The complete count of Overhead Transmission Lines (OTLs) is provided, indicating a sum of 297 lines. These lines can be further categorized as follows: 3 lines operating at a voltage level of 500 kV, 27 lines operating at a voltage level of 330 kV, 37 lines operating within the voltage range of 220-230 kV, and a significant number of 230 lines operating at 110 kV. Significantly, the cumulative extent of these Overland Transmission Lines (OTLs) measures a remarkable 8,589.3 kilometers. The evaluation of obsolete and unfeasible line lengths is of equal importance, highlighting potential difficulties within the current system. The data presents a nuanced depiction, suggesting that the 220-230 kV lines demonstrate the lowest proportion (38.2%) of these concerns, while the 330 kV lines are notable for having 62.6% of their extent classified as outdated or unfeasible. This complete overview highlights the necessity of continuous examination and feasible enhancements in the electrical transmission network to guarantee efficiency and dependability in the distribution of power.

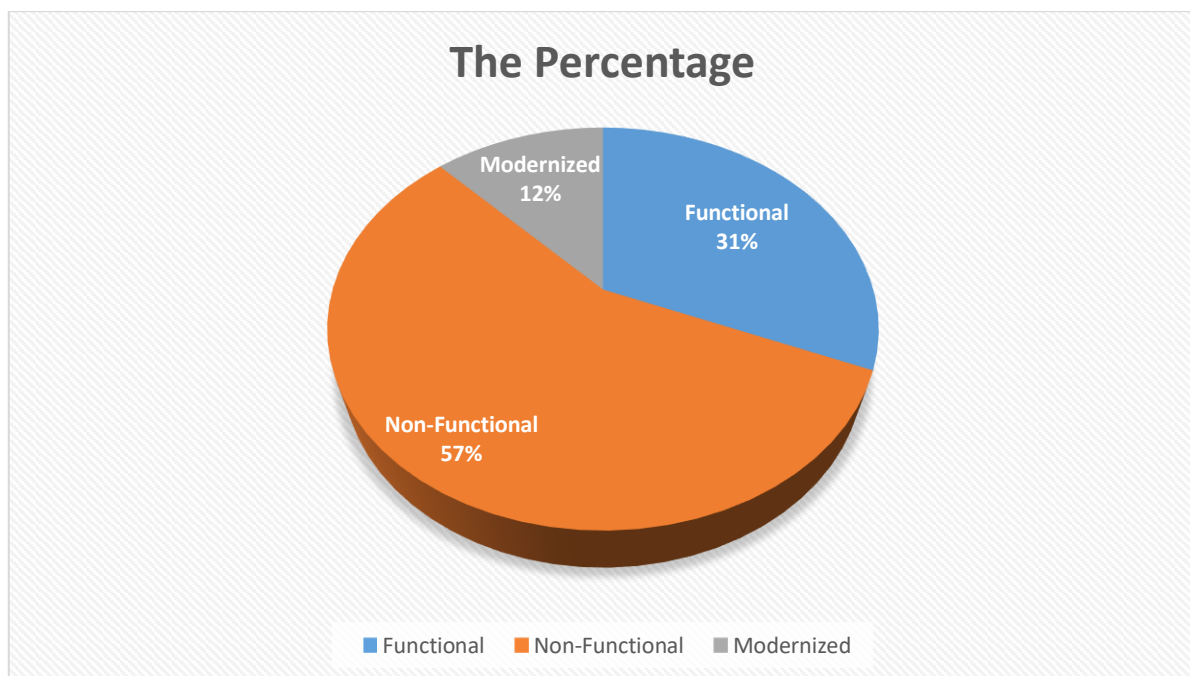


Fig. 2.2 Percentage of Lines in Operation

Since the installation of 28 % of overhead transmission lines and the use of existing conductors date back approximately 20 to 30 years, it indicates that the existing conductors are

about to complete their service period (2nd Binagadi, 1st Elet, 1st Ramana, 2nd Ramana and etc) and need to be replaced soon. Our country exchanges energy with neighbouring countries. For this reason, it is important to replace the existing conductors that were popular 30-40 years ago with new conductors and to establish new lines to integrate us with the European continent and surrounding countries in terms of energy exchange. However, today, the installation speed of new lines cannot parallel the increase in electrical energy production. Therefore, replacing the existing conductor instead of installing a new line will be more profitable in terms of time and cost. To increase in the transmission capacity of existing power lines, can be achieved by increasing the voltage or current, or both, with minimal changes (in terms of cost and labour) to existing structures [3]. Apart from these solutions, it is possible to increase the current carrying capacity of existing lines to transmit more current at higher temperatures [4,5] and in this way we can improve effectiveness.

CHAPTER THREE

Transmission Lines

3.1 Conductors Used in Power Transmission Lines

A transmission line is employed to facilitate the transfer of electrical electricity from a generating substation to multiple distribution units. The transmission of voltage and current waves occurs from one end to another. The system comprises a metallic framework that functions as a means of support for electrical cables, facilitating the transmission of energy across extensive distances.

Electrical transmission lines, characterized by their high voltage, constitute an integral component of the electric transport network, in conjunction with substations. Energy delivery remains feasible even in the event of an incident occurring during the transmission process. This is due to the linked nature of the system, which allows energy to be redirected from another line to reach its intended destination.

3.1.1 Conductors Used in Power Transmission Lines

Electrical conductors are vital to the reliable and effective functioning of power systems, as they assume a critical role in overhead transmission lines by primarily establishing the line's ability to transmit electrical current. The conductors utilized for overhead transmission and distribution lines consist mostly of aluminum wires that possess a high degree of homogeneity. In order to enhance their mechanical resilience, these aluminum wires are frequently reinforced with steel wires. Conventional conductors typically include aluminium conductors (AAC), all-aluminium alloy conductors (AAAC), and aluminium conductors steel reinforced (ACSR).

3.2.1 Conventional Conductors

All Aluminum Conductors (AAC) are defined as conductors with increased conductivity, consisting entirely of aluminium wound on top of each other in a braided form. These

conductors are generally used in residential areas, energy transmission lines with short pole spacing, and in the maritime industry due to their high corrosion resistance.

All Aluminum Alloy Conductors (AAAC) are composite conductors containing aluminium and aluminium alloy wires [6]. The corrosion resistance of this conductor shows higher corrosion resistance compared to other conventional conductors. Additionally, when examined mechanically, it is seen that it has a high mechanical resistance and a high weight and tension ratio. For these reasons, they are preferred in energy transmission and distribution lines [6, 7]. However, due to the high resistance resulting from the alloy they contain, they face higher power losses than AAC conductors [8]. Figure 2.1 shows the cross-section of AAC and AAAC conductors.

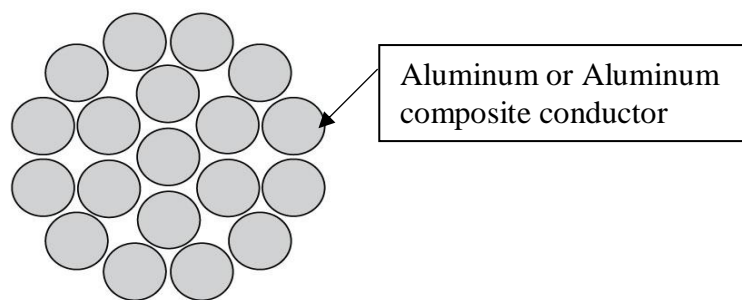


Fig 3.1 Cross-section of AAC and AAAC conductors [9]

If we look at the negative features of ACSR conductors, the galvanized steel wires in the middle of the conductors, which increase the strength, start to expand, and elongate after a certain temperature and additional electrical resistance occurs due to this elongation. This increases the temperature and overheats the conductor, causing power losses and creating more deflection [10]. In cases where the nominal operating temperatures of the conductors are exceeded, the lifespan of the conductors decreases dramatically due to the annealing process [11]. In addition, the aluminum wires of ACSR conductors, whose normal operating range is between 70-90 °C, become softer when the temperature exceeds 90 °C [12, 13], and therefore problems such as sagging and additional electrical resistance arise [10,14,15]. To avoid this problem, ACSR conductors' operation is limited to 75°C under 0.6 m/s wind speed [4].

Therefore, the current carrying capacity is negatively affected [16]. Despite these negative features, if ACSR conductor is desired to be used, galvanized steel wires are protected from corrosion by applying grease on them and wrapping them with a certain layer of PVC, at an extra cost [17].

The selection of overhead line conductors involves the consideration of numerous factors, with the foremost among them being the geographical and meteorological conditions of the region where these conductors will be deployed. This critical assessment encompasses the examination of parameters such as ice load mapping, incorporation of wind speed data, and an evaluation of potential environmental influences, such as the presence of industrial emissions, which may impact the chosen conductors. In addition to these, other factors that are taken into consideration are the temperature values the region reaches during the year and whether it is close to the sea [17]. In addition to this factor, the cost of the conductor itself and its supply cost are also among the factors considered when making the choice [18].

In these years when urbanization is rapidly increasing, energy demand is also increasing at the same rate. However, the infrastructure that will provide this energy cannot increase at the same rate. Additionally, due to excessive urbanization, it has become almost impossible to establish a new line. These statements are valid for countries with populations over 10 million. In Figure 1.2, the actual and forecasted maximum – minimum demand of Azerbaijan are represented. Considering all these, the current carrying capacity of existing transmission lines must be increased in order to meet these energy demands. Due to this need, HTLS conductors have emerged [17].

The table presents information regarding the highest and lowest levels of consumer demand seen on a monthly basis throughout an interval of five years, commencing from 2020 and concluding in 2025. Data plays a crucial role in comprehending and forecasting consumer behavior, strategizing resource allocation, and efficiently managing supply and demand. The

table presents a comprehensive depiction of consumer demand trends, facilitating the examination of recurring patterns and enabling the formulation of well-informed judgments.

The data indicates a steady upward trajectory in maximum consumer demand from 2020 to 2025. The observed phenomenon can be ascribed to a multitude of causes, encompassing economic circumstances, shifts in consumer conduct, and developments in technology. Gaining insight into the patterns of highest demand is crucial for anticipating peak periods and efficiently allocating resources to fulfill consumer requirements.

Table 3.1 Actual and Forecasted Maximum and Minimum Demand (MW) for 2020-2025

2020												
Months	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Max Demand	3426	3491	3339	2969	2860	3255	3605	3183	2990	2806	3346	3422
Min Demand	1836	1907	1867	1742	1612	1726	1975	1606	1603	1579	1695	1912
2021												
Max Demand	3333	3397	3342	3093	2973	3724	4021	4075	3684	3247	3498	3598
Min Demand	1848	1993	1915	1827	1617	1830	2117	2319	1585	1741	1939	2022
2022												
Max Demand	3515	3435	3459	3200	2968	3332	3838	3776	3679	2995	3292	3471
Min Demand	1974	2059	2047	1818	1711	1894	1984	2075	1637	1708	1833	1960
2023 (Actual)												
Max Demand	3480	3444	3287	3205	3080	3327	3757	4313	3724	2975		
Min Demand	1850	1990	1865	1880	1727	1814	1855	2007	1633	1639		
2024 (Forecast)												
Max Demand	3776	3690	3716	3438	3189	3580	4485	4544	4108	3621	3901	4012
Min Demand	2123	2214	2201	1955	1840	2037	2363	2589	1769	1943	2164	2257
2025 (Forecast)												
Max Demand	3905	3816	3842	3555	3297	3701	4440	4500	4248	3744	4033	4149
Min Demand	2195	2289	2276	2021	1903	2106	2443	2677	1829	2009	2238	2334

3.2.2 High Temperature Low Sag (HTLS) Conductors

HTLS are conductors that arise to solve the problems of bending and limited current carrying capacity in conductors [10]. In an overhead line, the power carrying capacity of short overhead lines up to 80 km can be limited by the nominal temperature, and lines with a length between 80 and 300 km can be limited by voltage stability, while in lines longer than 300 km, stationary stability becomes a critical factor [19]. If we look at the differences between HTLS conductors and ACSR conductors, the first ones that come to mind are that they can operate under higher temperatures, have better tensile strength and have a lower coefficient of thermal expansion, that is, they provide advantages in terms of deflection and elongation of the conductor. In addition, HTLS conductors have twice the current carrying capacity of ACSR conductors [5, 11, 20]. The voltage drop experienced by HTLS conductors in long transmission lines is a negative feature for this conductor [21]. For these reasons, HTLS conductors seem to be generally preferred in short transmission lines [9]. Considering all this, if we look at the main disadvantages of HTLS conductors, they appear to be high operating costs due to increased power losses and also conductor costs [22]. In addition, despite the many advantages of HTLS conductors, it is still a new conductor and some investors are still hesitant about its use because the conductor has not become fully widespread about what kind of reactions it will show under harsh operating conditions or what problems it may cause in long-term operations in natural working environments [23].

The balance sheet of Azerbaijan's AzerEnerji OJSC, specifically within the Regional Electric Network (REN) - High Voltage Electric Network (HVEN) LLC, enumerates a total of 285 systems dedicated to the management of electric transmission lines at voltage levels of 500 kV, 330 kV, 220 kV, and 110 kV. This comprehensive inventory is further categorized into 2 Long Transmission Lines, 19 Medium Transmission Lines, and 264 Short Transmission Lines.

This type of conductor can be employed in Azerbaijan's power grid for future projects and for the refurbishment of existing lines in need of significant repair.

Table 3.2 Technical specifications of HTLS conductors and ACSR conductors [25]

Type of Conductor		ACSR	G(Z)TACSR	(Z)TACIR	ACCC
Conductor	Outer Part	Hard Drawn Aluminium	Hard Drawn Aluminium	Hard Drawn Aluminium	Aluminium Composite Core
		1350-H19	1350-H19	ZTAL	1350-O
	Inner Part	Steel	Extra Reinforced Steel	Zirconium-Type Aluminium Conductor Reinforced	Composite Core
Diameter	mm	28,62	27,8	28,5	28,14
Cross Section	mm ²	484,5	469,5	413,4	519,7
Breaking Force	kN	131,9	149,2	130,4	183,3
Unit Weight	kg/km	1,621	1,616	1,625	1,565
Core Withstand Temperature	°C	170	200	300	>300
Tensile Strength	Aluminium	23-25	23-25	24-27	6-17
	Core	200-210	220	160-195	330-375
Conductivity	%	61	60	60	63
AC Resistance (75 °C)	Ω/km	0,0815	0,0878	0,0968	0,0662
Max. Operating Temperature	°C	78-85	150-510	210-230	180
Load Current	A	817	1503	1378	1600

HTLS conductors generally consist of two main components, carbon fiber composite core and trapezoidal stranded aluminum wires. Here, the aluminum wires with trapezoidal strips resemble a braid. This minimizes the gap between aluminum wires and allows us to put more aluminum wire than the amount of aluminum wire in conventional conductors with the same conductor diameter (round strip aluminum wire is usually used) [16, 24], and this is the factor that increases the amount of current transmitted [10]. Mechanical wear between the wires is as little as possible [24], and trapezoidal strip aluminum wires, although softer than the aluminum alloy, consist of annealed 1350-O type aluminum with high electrical conductivity, making the

conductor more efficient in transmitting electrical power [16]. In addition, another comparison data is that when HTLS conductors go beyond their nominal operating values and operate under these operating conditions for a certain period, there is no decrease in their lifetime [9].

Comparison of the technical properties of HTLS conductors and ACSR conductors with similar diameters is given in Table 2.1.

There are many HTLS conductors available today. In this study, the discussion primarily revolves around the frequent utilization of various conductor types, including Heat Resistant Zirconium-Aluminum Alloy Conductor Steel Reinforced, denoted as (Z)TACSR, the "Gap" variant of Heat Resistant Zirconium-Aluminum Alloy Conductor Steel Reinforced, referred to as G(Z)TACSR, as well as Heat Resistant Zirconium Aluminum Alloy Conductor termed (Z)TACIR. Additionally, the study also examines Aluminum Conductor Composite Core, which is known as ACCC [9].

(Z)TACSR conductors, which have the same structure as ACSR conductors, have galvanized steel wires in the core and heat-resistant aluminium-zirconium alloy wires, also known as Heat-Resistant Zirconium Aluminum Alloy Wires ((Z)TAL), on top of the core. We can understand that it is heat resistant from the letter T in the names of the conductors [17]. Considering the technical specifications, ACSR conductors can operate in the range of 70-90 oC, while (Z)TACSR conductor can operate in the range of 150-200 oC. In addition, the current carrying capacity of the (Z)TACSR conductor is twice as high as that of the conventional ACSR conductor. When we look at these two data and the mechanical evaluations above, it can be seen that if there is no sag problem and twice as much current will be carried, replacing conventional conductors will be advantageous in terms of both labour and cost [17].

G(Z)TACSR conductors are filled with heat-resistant grease to minimize friction between steel wires. The letter G in the name of the conductor means gap. There are also gaps between the trapezoidal aluminum strips and the steel wires. These conductors have low sag and can

operate at high temperatures [9]. In Figure 2.2, you can see a cross-sectional view of the G(Z)TACSR conductor.

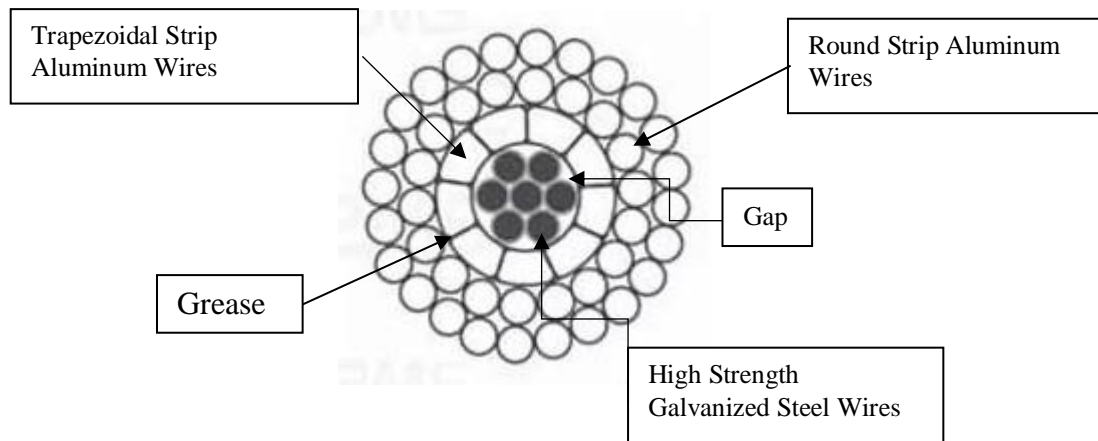


Figure 3.2 Cross Section Area of G(Z)TACSR Wire [17]

The ACCC (Aluminum Conductor Composite Core) represents a new generation of highly energy-efficient and thermally efficient conductors. It is constructed as a concentrically stranded conductor with multiple layers of trapezoidal-shaped, hard-drawn, and annealed 1350-0 aluminum wires surrounding a central core made of a lightweight carbon-glass fiber composite. The core made of carbon fiber is significantly superior to traditional steel cores, being 25% stronger and 60% lighter. The combination of this lightweight core and the unique trapezoidal shape of the aluminum strands allows ACCC to have over 28% more aluminum content without increasing its overall diameter or weight. This feature contributes to its enhanced electrical conductivity. ACCC is specifically engineered to operate reliably at elevated temperatures and maintains excellent sag characteristics across its operational temperature range. It is an excellent choice for upgrading existing transmission lines to boost their capacity. This conductor minimizes line losses and possesses remarkable self-damping properties. Furthermore, due to its high strength-to-weight ratio, ACCC can be used in longer spans, reducing the cost of supporting structures for new power lines. The cross-section of ACCC conductors is given in Figure 2.4.

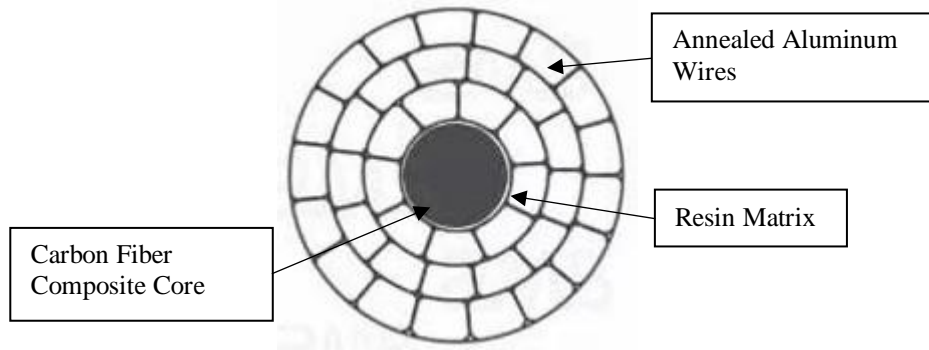


Figure 3.3 Cross Section Area of ACCC wire [26]

The assessment conducted in reference [26] examined the potential increase in capacity for an 11.5 km transmission line. This transmission line is characterized by a single-bundle, double-circuit configuration operating at a voltage level of 220 kV. The objective of the evaluation was to determine the feasibility of doubling the line's capacity. The proposed strategy involved the construction of new towers utilizing twin-bundle ACSR conductors, while simultaneously preserving the existing right of way. High-temperature low-sag (HTLS) conductors have the potential to utilize the current towers, however with the requirement of modifying the suspension structure. Based on the findings of reference [26], it has been observed that the expenses associated with demolition, building, and installation of ACSRs (Aluminum Conductor Steel Reinforced) conductors constitute approximately 25-33% of the total expenditures. However, in the context of upgrading with HTLS (High-Temperature Low-Sag) conductors, the aforementioned costs are deemed to be insignificant. This holds true across various types of HTLS conductors that have been evaluated. The expenses related to traditional ACSR conductors account for approximately 9.0% of the overall project expenditures, but the expenses connected with HTLS conductors are contingent upon the specific type of conductor, ranging from 5.3% to 12.5%. The present analysis draws the conclusion that the predominant expenses in question are those related to power losses. Specifically, these costs account for about 67.4% when employing ACSR conductors and exhibit a range between 86.4% and 93.5% when utilizing HTLS conductors. According to

reference [26], Table 2.2 presents the comparative expenses associated with the enhancement of a 220 kV transmission line. The additional energy dissipation observed in HTLS conductors, as indicated in Table 2.2, can be attributed to their operating at higher temperatures in comparison to ACSR conductors.

Table 3.3 Costs Associated with the Renovation of a 220 kV Transmission Line

Conductor Type	Percent Costs			
	Demolition	Construction + Installation	Conductor	Energy Loss
ACSR	1.1%	22.5%	9.0%	67.4%
HTLS (5 types)	0.4–0.7%	0.7–1.2%	5.3–12.5%	86.4–93.5%

3.3 Additional Loads on Conductor

When performing mechanical assessments for overhead line conductors, it's crucial to consider the local weather conditions of the installation area. These environmental factors, such as temperature fluctuations, the accumulation of extra ice, and the impact of wind and ice combined, introduce additional mechanical loads on the conductor. Icing typically occurs on the conductor when temperatures range from -8 to 2 °C. Below -10 °C, the air's humidity decreases significantly, preventing the formation of ice. In regulatory standards, the threshold temperature for considering ice formation is set at -5 °C. In addition, the calculation of the additional ice load was simplified by finding an empirical formula in (2.1) [27].

$$g_{ice} = k\sqrt{d} \quad 3.1$$

g_{ice} : Ice load on conductor (kg/m)

k : Coefficient

d : Diameter of conductor (mm)

The added ice load applies as a vertical force, while the extra wind load exerts a horizontal force. When considering a situation with a 100% ice load, you calculate the unit weight of the

ice-loaded conductor by substituting the conductor's weight along with the ice load into equation (2.2).

$$g_{100} = g_{ice} + g_w \quad 3.2$$

g_{ice} : Ice load on conductor (kg/m)

g_{100} : Unit weight of ice loaded conductor (kg/m)

g_w : Unit weight of the conductor (kg/m)

In the event of a 100% wind load scenario, the result is derived using the equation outlined in (2.3).

$$w_{100} = \sqrt{w_w^2 + g_w^2} \quad 3.3$$

w_{100} : Unit weight of wind loaded conductor (kg/m)

w_w : Wind load on conductor (kg/m)

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CHAPTER FOUR

Birds Protection and Safety Research of Transmission Line

Within the first 8 months of 2023, there were 269 faults caused by different reasons in the transmission line of 220 kV – 500 kV. These reasons are primarily divided into 2 main groups – Internal faults and External faults. Automatic reclosure was effective in resolving 24.9% of only 67 errors that occurred. Fig 3.1 displays the statistics regarding the faults of transmission lines during the initial 8 months of 2023 in the Republic of Azerbaijan. Typically, operational faults arises from equipment reaching the end of its life cycle and contributes to 18.21% of all errors. In this context, external factors are the primary catalyst for transmission line activations, making up 81.79%.

Table 4.1 Number of Faults Caused by Birds

Reason of Short Circuit	Network	110 kV	220 kV	330 kV	500 kV	Total:
Due to the presence of Birds	Absheron	0	0	0	0	0
	Baku	0	0	0	0	0
	Sumgayit	2	0	0	0	2
	Xachmaz	5	0	0	0	5
	Shirvan	6	2	6	0	14
	Ganja	0	0	0	0	0
	Mingachevir	24	0	2	0	26
	Gabala	2	-	-	-	2
	Karabakh	10	-	2	-	12

Among these external factors, the most prominent triggers are incidents involving birds, which are responsible for 32.17% of external influences and 24.16% of all activations. Over the past three years, due to the optimization of measures to prevent bird-related incidents and improvements in the management of operations and maintenance by various units, there has been a noticeable decrease in bird-related faults. This positive trend has been accompanied by ongoing enhancements to the ecological environment.

Table 4.2 Reasons of Faults for 110-500 kV Transmission Lines in 8 Months of 2023

№	Reason of Short Circuit	110 kV	220 kV	330 kV	500 kV	Total:	Recloser
1	Damage and short circuit of insulators	33	0	8	0	41	17
2	Wire damage, breakage	1	-	0	-	1	-
3	Armature damage, breakage	5	-	1	-	6	1
4	Damage to the cable	1	-	-	-	1	-
5	Damage to the support, overturning	1	-	-	-	1	-
6	Equipment damage and operational errors in substation	3	0	1	1	5	1
7	Fire	0	0	5	-	5	2
8	Trees touching the line	1	1	0	-	2	-
9	Reason of aging	4	-	1	-	5	2
Total:		49	1	16	1	67	23
10	Problem in substation belonging to "Azerishiq" OJSC	12	2	-	-	14	3
11	Problem in substation belonging to Azerbaijan Railways LLC	14	0	0	0	14	1
12	Due to vehicles	8	0	1	0	9	-
13	Due to presence of birds	53	2	10	-	65	19
14	Extraneous waste falling on the wire	5	1	0	0	6	1
15	External interference (for various reasons)	4	0	2	-	6	1
16	Abnormal weather conditions (wind, lightning)	20	2	3	3	28	6
17	Equipment damage in Ess	2	-	-	-	2	-
18	Defects in IIR, Georgia and RF	-	5	2	1	8	3
19	Unknown reason	37	3	8	2	50	10
Total:		155	15	26	6	202	44
GRAND TOTAL:		204	16	42	7	269	67

4.1 Bird Protection Types

Bird thorn is an effective solution for deterring birds from entering protected areas. When birds land within its perimeter, bird thorn pricks them, discouraging them from staying or engaging in other activities. Bird thorn is advantageous due to its affordability, durability, consistent bird-repelling capabilities, and suitability for widespread use. It boasts simplicity in production, easy installation, and a strong overall anti-bird performance.

The information regarding the quantity of short circuits that occurred at each of the different voltage levels is represented in the table that can be found below. Also it goes deeper and shows which Regional Electrical Network is responsible for it. Furthermore, it delves

deeper into the matter and clarified the specific Regional Figure 3.1 illustrates the scalable anti-bird needle plate, which shares the same principle as bird thorns by utilizing space to deter birds. The structure is riveted, eliminating welding points and preventing steel needle detachment. The device's size is adjustable based on density and length for tailored protection.

The steel needles, made of 304 cold-drawn stainless steel wire, are at least 200 mm long and have injury-preventing tips. Each plate has a minimum of 18 steel needles, each with a diameter of 2.5 mm. When fully extended, the needle gap does not exceed 70 mm, with a maximum length of 140 mm and a width under 80 mm. At a 90-degree angle between substrates, the length reaches 500 mm, and the width is 60 mm. Furthermore, the needle plate passes a 168-hour neutral salt-fog test without developing red rust, demonstrating strong corrosion resistance [30].



Fig. 4.1 Anti – Bird Needle Plate [30]

Figure 3.2 illustrates the insulated anti-bird cone, which operates on a principle similar to that of bird thorns. The base of this device is equipped with Nd-Fe-B magnets for direct attachment to the cross-arm of the tower. To address the issues of bird thorns being susceptible to trampling and deformation, the insulated anti-bird cone features a streamlined taper design. The use of strong magnet adhesion resolves problems related to securing and replacing bird-

thorn bolts. Additionally, reinforced nylon material is employed to combat rust and breakage typically associated with metal bird thorns. Lastly, a combined array approach is adopted to address the limitations of using individual bird thorns.

This device possesses several notable characteristics, including lightweight construction, resistance to aging, high strength, excellent insulation properties, flexible combinability, and easy installation. Its robust magnet adhesion can withstand gale-force winds of up to ten levels without shifting, effectively deterring birds from lingering, trampling, or causing damage, while also expanding the available space for occupation and defense.

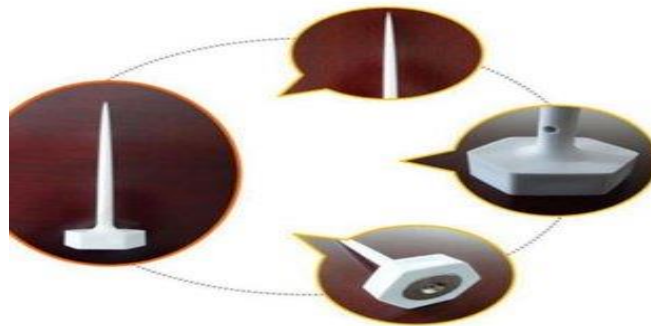


Fig. 4.2 Insulated Anti – Bird Cone [28]

Birds exhibit limited adaptability to a 532 nm green laser. As depicted in Figure 3.3, the device incorporates intelligent laser emission settings that allow for programmable control of laser emissions at various times and frequencies. This capability effectively minimizes birds' ability to adapt to the laser beams over time, ensuring that the device remains operational even with prolonged use. The device is equipped with a laser array capable of emitting lasers in a 180-degree pattern, providing extensive coverage [28,29].



Fig. 4.3 Bird Repellent Device of Laser [29]

As illustrated in Figure 4.3, this device prevents birds from nesting by utilizing the space-occupying effect. Additionally, its needle-like design addresses the limitations of traditional spacers, such as wind blockage and rain sheltering. This device boasts a 360-degree rotation capability and straightforward installation. It offers ample working space for maintenance personnel on the cross arm. The umbrella-type anti-bird device has been extensively implemented on the 220kV lines managed by Jining Company. Remarkably, no bird nests have been detected within the protection area, underscoring the device's effectiveness [31].

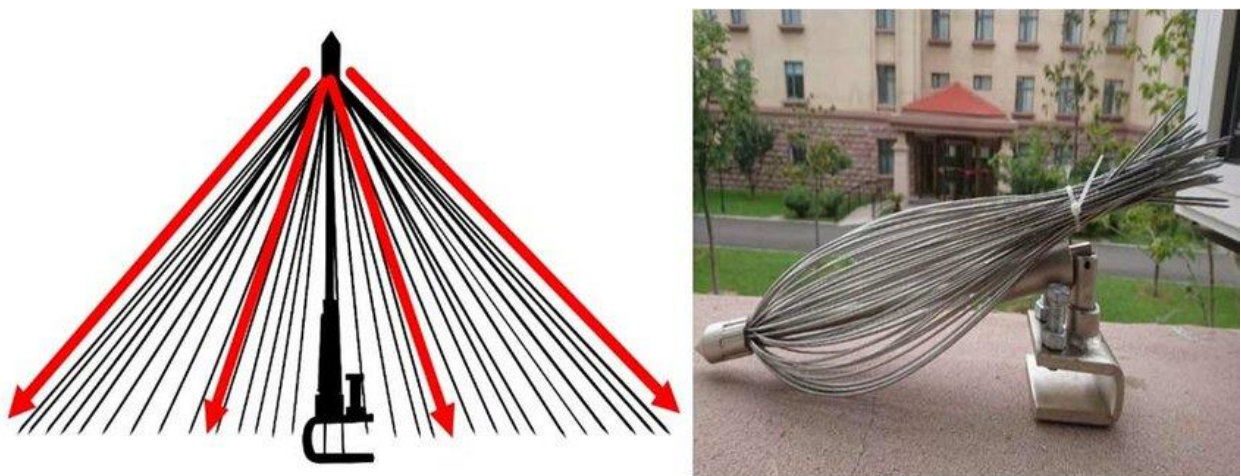


Fig. 4.4 Anti – Bird Device of Umbrella Type [31]

It is recommended that these installations be implemented throughout the air route across the regions of Goranboy, Yevlax, Barda, Agjabedi, Salyan, Masalli, and Ujar, which are characterized by a significant population of birds of all kinds. Consequently, it is anticipated that the installation of the proposed design will lead to a 60% decrease in the occurrence of unintentional openings created by avian species on the power wires.

Preventive measures are consistently implemented to mitigate the occurrence of unexpected short – circuited in overhead transmission lines. Overhead lines are cleared of bushes and reeds to prevent fires, dirty insulators are washed, defective insulators are replaced. Inspection of supports from above, defective line fittings are replaced with new ones, bird nests are removed, extraneous waste is removed. Inspection and repair of bolt connections of loops

on anchor supports. The places where the dimensions of the overhead lines are less than the norms are identified and adjusted, and trees are regularly pruned under the wires and in the protection zones. Anti-bird arrangements are installed to prevent birds from getting electrocuted and fouling the insulator strings. End couplings of OTLs with cable parts are removed, trenches with intermediate couplings are checked. Lines are inspected at night to detect overheating of overhead wires at junctions and severe crowning of insulator chains.

CHAPTER FIVE

“Azerbaijan” Power Plant

5.1 Project Proposal for “Azerbaijan” Power Plant

The 2400 MW ‘Azerbaijan’ Thermal Power Station is a critical component of the Republic's electrical grid. As part of the Renovation Program, the station experienced the restoration of approximately 600 MW of lost generation power. Additionally, the manufacturer-established normal operating characteristics were put back for the station's technical and economic indicators, and its operational lifespan was prolonged by a minimum of 20 years. In addition, maintenance equipment and auxiliary workshops, in addition to 500 and 330 kV substations, were fully rebuilt and put into operation on June 25, 2020. The actual parameters of the power units at the Azerbaijan Thermal Power Station is as follows:

- Efficiency is 38.5%
- The conventional amount of fuel used for the production of 1kW*hour of electricity is 335 grams, which is more than that of modern stations. This, in turn, causes more natural gas consumption.

Based on the findings of this study, considering the standard features of the primary equipment installed at the station, it is feasible to enhance the efficiency of useful work and reduce the conventional fuel consumption for electricity generation through the implementation of innovative technologies in certain components of the power units.



Fig. 5.1 3D Graphics of ‘Azerbaijan’ Power Plant

Taking into consideration the prospect of territory extension following the completion of power units No. 7 and 8 of the "Azerbaijan" TPP as well as the most recent commissioning dates of these units, it becomes necessary to carry out modernization works by installing gas turbines in power units No. 7 and 8. During the initial phase, the proposal calls for the implementation of modernization projects, which include the installation of four gas turbines (two on each steam turbine in power units No. 7 and 8) of the station, for a combined capacity of 1280MW (4x320MW). The advantageous geographical positioning of the Azerbaijan thermal power plant, coupled with its site at the intersection of critical electricity export corridors, gives that area exceedingly advantageous for the development of new generation capacities from both a technical and economic standpoint.

Furthermore, without the need for an additional high-voltage substation to be constructed, the electricity generated in the new generation sources can be transferred to the energy system of the Republic via the existing 330 and 500kV substations of the "Azerbaijan" thermal power station.

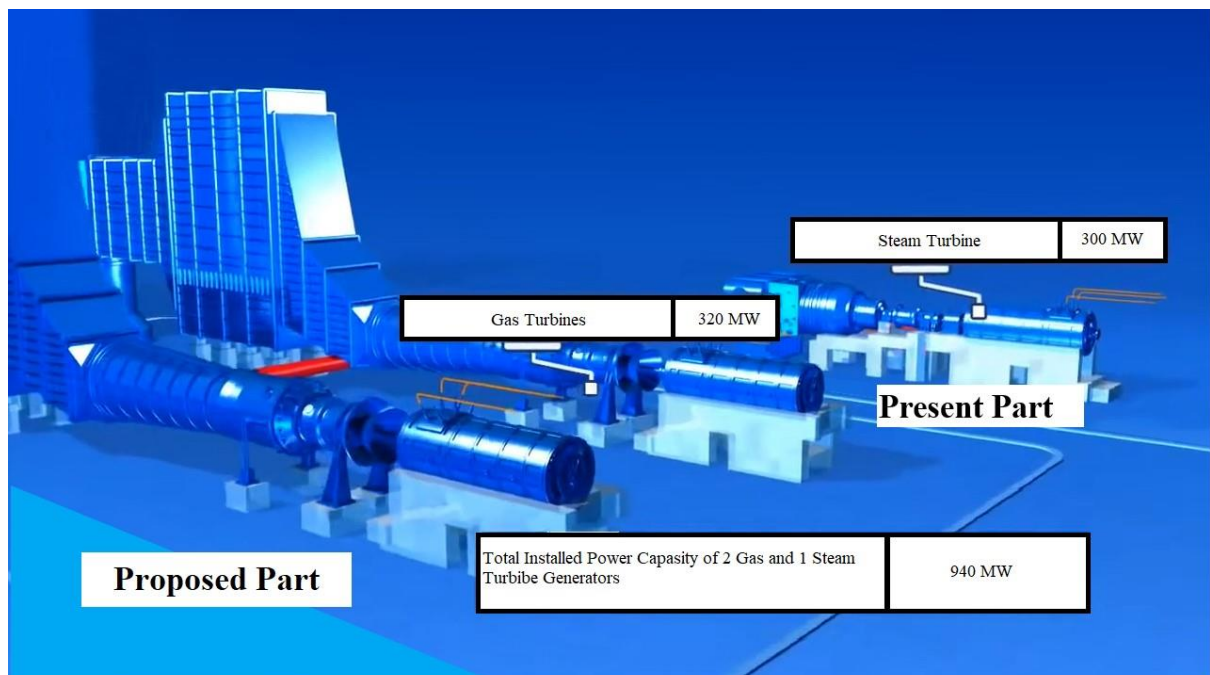


Fig. 5.2 Proposed Project for Azerbaijan Power Plant

The total amount of conventional fuel utilized in power units to generate 1 kilowatt-hour of electricity will decrease by 110 – 80 grams, reaching 255 – 225 grams. 17% of energy blocks will have a higher efficiency, reaching 55.5% of their potential. Considering the inclusion of an additional 6 energy units, each with a capacity of 1800MW, along with the recent establishment of an 1880MW capacity, the cumulative installed capacity of the "Azerbaijan" thermal power plant will amount to 3680MW. During peak demand periods, the "Azerbaijan" TPP, with a capacity of 3400MW, operates at full capacity. At this level of operation, the plant requires 255 grams of conventional fuel to produce 1kW of electricity. This represents a reduction of 80 grams in the amount of conventional fuel used for the production of 1kW of electrical energy by the power station. Considering the decrease in conventional fuel consumption by 110 grams per 1 kilowatt of electricity generated, it is projected that an annual saving of 1.2 billion cubic meters of natural gas will be achieved. This calculation takes into account the prevailing domestic selling price of natural gas, which is 1000 cubic meters for 165 Azerbaijani Manat (AZN). Consequently, this reduction in natural gas consumption will result in an annual financial saving of approximately 198 million AZN.

5.2 Simulation

The aforementioned information and forecasts are derived from simulations conducted using the DIG Silent Power Factory software application. The associated images depict statistics pertaining to the highest demand scenario in 2023, together with a forecast for the greatest demand in 2025. The following images depict simulated representations of the system's schematics. Figure 4.3 illustrates the operational scenario of the Azerbaijan Thermal Power Plant (TPP) in the year 2023. On August 14th, the largest demand recorded was 4313 MW.

It is shown in the graphic that a total of 6 out of 8 generators were interconnected with the power grid in order to meet the demands of consumer consumption. The total energy system

had an average fuel usage of 272.24 grams in order to generate one kilowatt-hour in this particular instance.

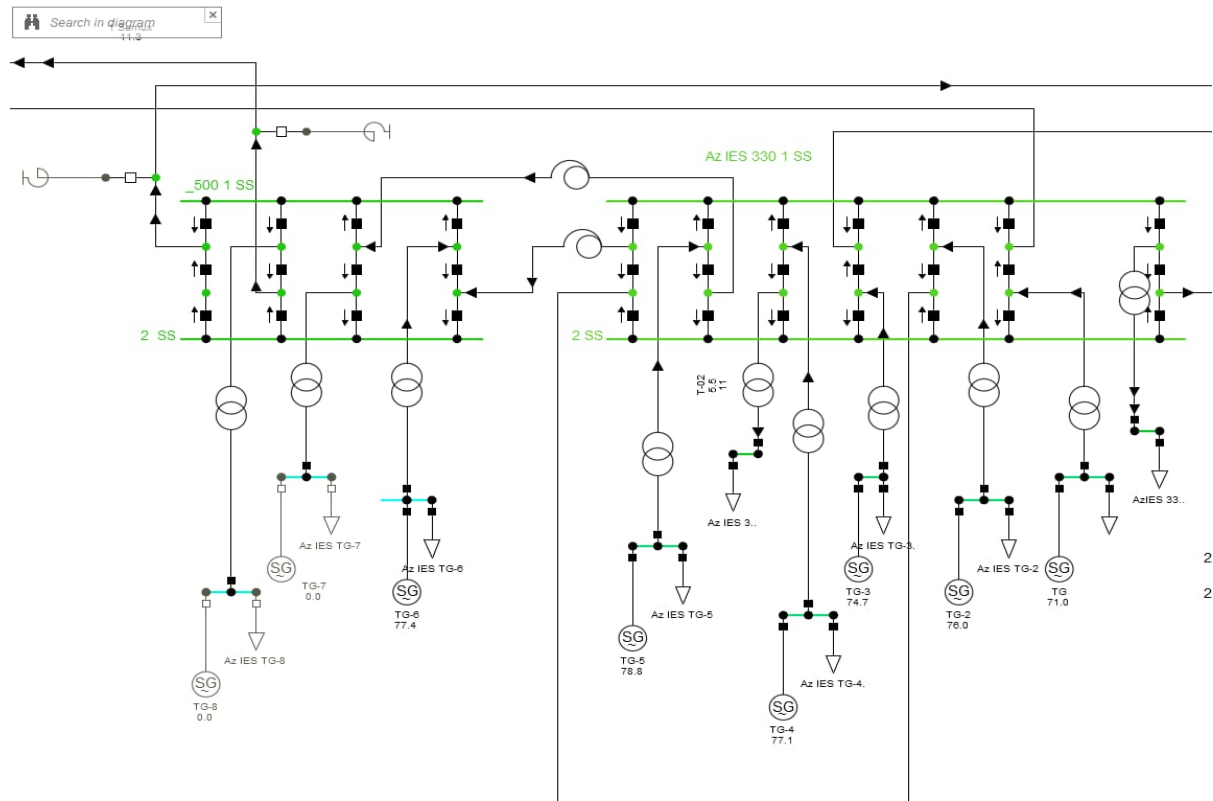


Fig. 5.3 Maximum Demand for the "Azerbaijan Power Plant" Operating Case in 2023

Table 5.1 The Parameters of Generators

№ of Generator	Parameters			
	P (Active Power)	Q (Reactive Power)	S (Apparent Power)	cosφ
G_1	262 MW	23 MVAR	263 MVA	0.996
G_2	263 MW	20 MVAR	263.7594 MVA	0.997
G_3	259 MW	34 MVAR	261.2221 MVA	0.991
G_4	267 MW	17 MVAR	267.5406 MVA	0.998
G_5	273 MW	15 MVAR	273.4118 MVA	0.998
G_6	273 MW	17 MVAR	273.5288 MVA	0.998

The table 5.1 presents the parameters of the generators, including active, reactive, and apparent power, as well as power factor.

The situation would undergo a transformation if gas turbines were integrated into the system. If a simulation is performed based on our project and a maximum demand forecasting for 2025, the results that follow will be obtained. Figure 4.4 displays a visual representation of the simulation.

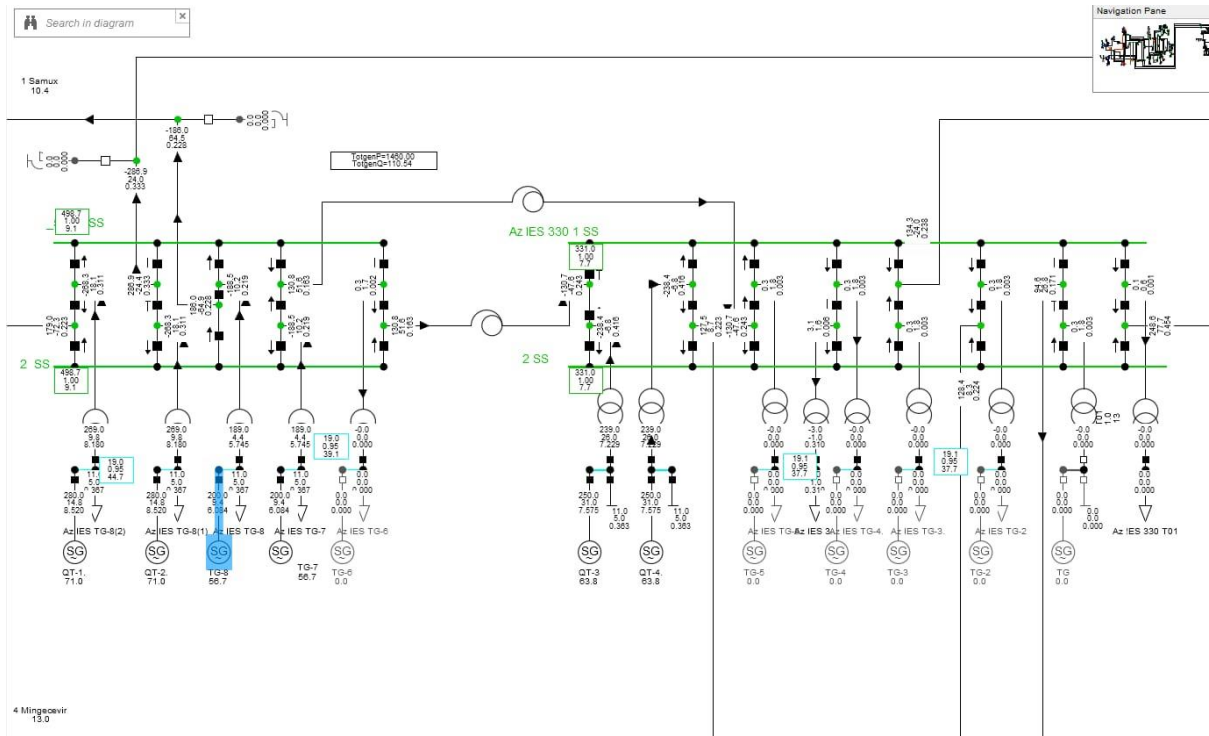


Fig. 5.4 Maximum Demand for the "Azerbaijan Power Plant" Operating Case in 2025

As previously stated, the system's efficiency would be increased to 55 percent through the utilization of gas turbines. According to the projected demand for the year 2025, which is estimated to be 4500 MW, it is recommended to utilize four gas turbines together with an additional two steam turbines in order to enhance overall efficiency. Utilizing this approach allows us to successfully supply energy to the people who will ultimately be using it. While this is going on, it will also be an extremely important factor in the process of frequency regulation.

Table 5.2 The Parameters of Gas – Turbine and Steam Turbine Generators

№ of Generator	Parameters			
	P (Active Power)	Q (Reactive Power)	S (Apparent Power)	cosφ
GT_1	280 MW	30 MVAR	281.6026 MVA	0.994
GT_2	280 MW	36 MVAR	282.3048 MVA	0.992
GT_3	250 MW	20 MVAR	250.7987 MVA	0.996
GT_4	250 MW	20 MVAR	250.7987 MVA	0.996
G_7	262 MW	23 MVAR	263.0076 MVA	0.996
G_8	200 MW	32 MVAR	202.5438 MVA	0.987

In order to determine the average fuel consumption of the system, it is necessary to initially analyze the energy production on an hourly basis. The subsequent tables present data related to the projected energy production for a scenario of peak demand in the year 2025. In addition, we also take into account the auxiliary utilization, and thereafter perform a calculation based on the electrical supply derived from the bus-bar.

Based on our projections of energy output, it has been determined that the power plant will generate a total of 30,228,000 kilowatt-hours (kWh) on the specified day. However, only a small proportion will be provided for auxiliary supply, and the amount of energy that will be directed to the system can be determined through the bus-bar.

$$30228000 - 1026720 = 29201280 \text{ kW}\cdot\text{h} \quad 4.1$$

In order to determine the total fuel consumption of the 'Azerbaijan' Power Plant, a series of actions must be undertaken and the plant requires 255 grams of conventional fuel to produce 1kW of electricity.

$$\frac{\text{Total fuel} * 1000}{\text{Using electrical energy from the bus} - \text{bur}}$$

$$= \text{Fuel used to produce 1 kW} * h$$

4.2

where 1000 a constant value.

Table 5.3 The Production of Electricity in Power Station based on hourly demands

Hours	Azerbaijan Thermal Power Plant
	MW (Forecasted)
1	1000
2	1000
3	900
4	900
5	900
6	900
7	900
8	1000
9	1000
10	1350
11	1450
12	1450
13	1597
14	1597
15	1597
16	1597
17	1450
18	1450
19	1300
20	1200
21	1470
22	1470
23	1400
24	1350
Total	30228

In this analysis, we consider all of the stations and arrange the respective values in order to compute the average fuel consumption of the system. In the present scenario, my attention is solely directed at one specific power plant, while the remaining factors will remain unchanged as per the existing norms, which aren't projected to undergo any modifications within a two-year timeframe. The table presented below has all the specific data.

$$\frac{255 * 29201280}{1000} = 7446.326 \quad 4.3$$

Table 5.4 Information on thermal power plants

Stations	Production of electricity thousand kW*h	Total fuel consumption ton	Gr/kW*h	Using Electricity from the bus – bur
Azerbaijan	30228.000	7446.326	255	29201.280
Cenub	14682.711	3410.508	236.76	14404.947
Shimal-1	7834.050	1678.999	219.726	7641.260
Shimal-2	8857.500	1836.492	212.775	8631.148
Astara	1015.000	295.858	298.49	991.181
Lerik	124.400	36.605	304.22	120.323
Sheki	1066.000	296.656	285.15	1040.350
Xachmaz	984.000	283.507	294.95	961.210
Baku CHP	983.250	386.389	410.13	942.110
Baku	1713.000	470.971	280.92	1676.520
Sumgait	10386.176	2366.980	232.27	10190.516
Sangachal	3229.100	898.406	284.47	3158.200
Gobu	7865.800	2047.424	264.29	7746.940
Shahdag	1523.900	443.162	296.29	1495.720
Total	90492.887	21898.283		88201.705

By employing Equation 4.2, it is possible to determine the overall average grams per kilowatt-hour (gr/kW*h) of the entire system.

$$\frac{21898.283}{88201.705} * 1000 = 248.275 \text{ gr} \quad 4.4$$

Based on the conducted simulation and calculation, it has been determined that the average gram per kilowatt-hour (kWh) for the system will be 248.275 gr/kWh. It is important to note that all other station values will remain unchanged from their current values. To compare this outcome to the maximum of 272.24 grams per kWh in 2023. Fuel usage across the board would decrease by 23.965 gr/kWh.

CHAPTER SIX

Conclusion and Future Research

6.1 Conclusion

To sum up, through the simulation and calculation performed, it has been determined that the average gram per kilowatt-hour (kWh) for the system will be 248.275 gr/kWh. It is crucial to emphasize that all other station values will stay unaltered from their current values. To make a comparison, this result can be contrasted with the highest value of 272.24 grams per kilowatt-hour achieved in 2023. The overall fuel consumption would drop by 23.965 grams per kilowatt-hour. With a reduction of 110 grams per kilowatt of power produced, it is estimated that an annual savings of 1.2 billion cubic meters of natural gas will be attained. This estimate considers the current domestic selling price of natural gas, which is 1000 cubic meters for 165 Azerbaijani Manat (AZN). As a result, the decrease in natural gas usage will lead to an estimated yearly cost savings of almost 198 million AZN.

Therefore, it is expected that implementing the suggested bird protection design will result in a 60% reduction in the frequency of accidental openings caused by birds on the electrical cables. The costs associated with conventional ACSR conductors make up around 9.0% of the total project expenses. However, the costs linked to HTLS conductors depend on the particular type of conductor and might range from 5.3% to 12.5%. The current research concludes that the primary expenditures in question are those associated with power losses.

The quest for sustainable energy drives the exploration of innovative methods and technologies to enhance the efficiency of energy systems. This chapter provides a comprehensive overview of key advancements for further readings that collectively contribute to a more sustainable and resilient energy future.

6.2 Future Research

Smart grids form the backbone of modern energy systems, utilizing advanced sensors, communication networks, and automation to optimize electricity distribution. This section explores the role of smart grids in reducing losses and improving reliability [32].

Addressing the intermittency of renewable energy, this section delves into advanced energy storage technologies, including lithium-ion batteries, flow batteries, and compressed air energy storage. These systems play a crucial role in storing and releasing energy during peak demand periods.

Empowering consumers to actively participate in energy conservation, demand response programs enable the dynamic adjustment of electricity consumption based on real-time pricing or grid signals. This section explores how these programs contribute to a flexible and optimized energy demand.

Integration of renewable energy sources, such as solar and wind power, is examined in this section. Advanced forecasting techniques and energy management systems optimize the utilization of intermittent sources, ensuring a stable power supply [1].

Smart building technologies and energy-efficient solutions contribute significantly to reducing overall energy consumption. This section explores the impact of advanced lighting, HVAC systems, and building automation in various settings, from residential to industrial buildings [32].

Simultaneously generating electricity and useful heat, CHP systems enhance overall energy efficiency. This section investigates the principles and applications of CHP systems across different sectors to maximize energy utilization.

Smart meters and advanced metering infrastructure provide real-time insights into energy consumption. This section explores how Advanced Metering Infrastructure (AMI) empowers

consumers with information for informed decision-making, promoting energy conservation and system efficiency [33].

Artificial intelligence and machine learning algorithms play a crucial role in optimizing energy system operations. This section explores their applications in predicting demand patterns, identifying inefficiencies, and dynamically adjusting energy production and consumption.

The integration of Internet of Things (IoT) devices and sensors for real-time monitoring and control is discussed in this section. IoT technologies enable better decision-making, predictive maintenance, and overall optimization of energy systems [34].

Advancements in electric vehicles, high-efficiency transportation systems, and alternative fuels are explored in this section. The role of transportation in overall energy consumption is considered, and innovative solutions for reducing its environmental impact are discussed.

In conclusion, this chapter provides a comprehensive exploration of innovative methods and technologies for enhancing the efficiency of energy systems which can be used for future investigations. A holistic approach that integrates these advancements is essential for achieving significant improvements in energy sustainability and resilience. Policy incentives, regulatory support, and public awareness are crucial components for the successful implementation of these innovations in diverse energy landscapes.

REFERENCE

- [1] A. Tural, N. Zalov, and I. Guliyev, "Integration of Renewable Energy Sources to Power Grid in Azerbaijan: A Review," 2023 IEEE 17th International Conference on Application of Information and Communication Technologies (AICT), Baku, Azerbaijan, 2023, pp. 1-6, doi: 10.1109/AICT59525.2023.10313196.
- [2] (Müstəqillik əldə edildikdən sonra elektroenergetikanın inkişafı (1991-ci ildən sonrakı üçüncü dövr) |Azərbaycan Energetika Nazirliyi. (2020, February 2). Azərbaycan Energetika Nazirliyi. <https://minenergy.gov.az/az/elektroenergetika/musteqillik-elde-edild>)
- [3] I. Ardelean et al., "Case study on increasing the transport capacity of 220 kV DC OHL Iernut-Baia Mare by reconductoring using LM technologies," May 102 2011. Accessed: Jun. 16, 2022. [Online]. Available: <http://dx.doi.org/10.1109/tdcllm.2011.6042216>
- [4] K. Kopsidas, "Modelling thermal rating of arbitrary overhead line systems," (PhD Thesis, The University of Manchester). The University of Manchester.
- [5] A. A. P. Silva and J. M. B. Bezerra, "Applicability and limitations of ampacity models for HTLS conductors," Electric Power Systems Research, vol. 93, pp. 61–66, Dec. 2012, doi: 10.1016/j.epsr.2012.07.003.
- [6] IEEE Power and Energy Society, "IEEE guide to the installation of overhead transmission line conductors," IEEE Std 524-2003 (Revision of IEEE Std 524- 1992) 2004, 1–141
- [7] T.C. Milli Eğitim Bakanlığı, "Havai Enerji Hatları," https://megep.meb.gov.tr/mte_program_modul/moduller_pdf/Havai%20Enerji%20Hatları.pdf
- [8] S. N. Mohtar, M. N. Jamal, and M. Sulaiman, "Analysis of all aluminum conductor (AAC) and all aluminum alloy conductor (AAAC)." Accessed: Jun. 16, 2022. [Online]. Available: <http://dx.doi.org/10.1109/tencon.2004.1414794>

- [9] J.-R. Riba, Santiago Bogarra, Á. Gómez-Pau, and M. Moreno-Eguilaz, “Uprating of transmission lines by means of HTLS conductors for a sustainable growth: Challenges, opportunities, and research needs,” *Renewable and Sustainable Energy Reviews*, vol. 134, p. 110334, Dec. 2020, doi: 10.1016/j.rser.2020.110334
- [10] Rashmi, G. S. Shivashankar, and Poornima, “Overview of different overhead transmission line conductors,” *Materials Today: Proceedings*, vol. 4, no. 10, pp. 11318–11324, 2017, doi: 10.1016/j.matpr.2017.09.057
- [11] A. Gó. Exposito, J. R. Santos, and P. C. Romero, “Planning and Operational Issues Arising from the Widespread Use of HTLS Conductors,” *IEEE Transactions on Power Systems*, vol. 22, no. 4, pp. 1446–1455, Nov. 2007, doi: 10.1109/tpwrs.2007.907151.
- [12] I. Albizu, A. J. Mazón, V. Valverde, and G. Buigues, “Aspects to take into account in the application of mechanical calculation to high-temperature low-sag conductors,” *IET Generation, Transmission & Distribution*, vol. 4, no. 5, p. 631, 2010, doi: 10.1049/iet-gtd.2009.0543.
- [13] S. C. Nogales, J. A. L. Miñana, A. Alonso, M. P. Comech, M. García-Gracia, and E. Martín, “HTLS and HVDC solutions for overhead lines uprating,” In *Proc. of the 11th Spanish Portuguese Conference on Electrical Engineering*, 2009, 1-5.
- [14] T. Hill, D. Bryant, “Experience and benefits of using high temperature low sag (HTLS) overhead conductors,” In *24th AMEU Technical Convention*, 2013, 1-5.
- [15] IEEE Power and Energy Society, “1283-2013-IEEE guide for determining the effects of high-temperature operation on conductors, connectors, and accessories,” 2013. New York.
- [16] N. B. A. Nasuruddin, A. B. Ariffin O. Ryuta, “High temperature low sag (HTLS) overhead transmission line conductor,” *22nd Conf Electr Power Sup Ind CEPSI*, 1–8.
- [17] S. Karabay, A. Şen, “Enerji nakil hatlarının ekonomik ömürlerinin tamamlanması safhasında kullanılabilecek yeni nesil havai hat iletkenleri ve malzemeleri”.

- [18] H. B. D. Yasaranga, W. D. A. S. Wijayapala, and K. T. M. U. Hemapala, “Techno Economic Analysis of the Use of High Temperature Low Sag (HTLS) Conductors in the Sri Lanka’s Transmission System,” *Engineer: Journal of the 105 Institution of Engineers, Sri Lanka*, vol. 50, no. 1, p. 41, Feb. 2017, doi: 10.4038/engineer.v50i1.7243.
- [19] L. Dawson and A. M. Knight, “Transmission line length, operating condition and rating regime,” May 2016. Accessed: Jun. 16, 2022. [Online]. Available: <http://dx.doi.org/10.1109/ccece.2016.7726807>
- [20] F. Misaghi and T. Barforoushi, “Evaluation of regulatory impacts on investments of distributed generation and upstream network under uncertainty: a new stochastic bi-level model,” *CIREN - Open Access Proceedings Journal*, vol. 2017, no. 1, pp. 2744–2748, Oct. 2017, doi: 10.1049/oap-cired.2017.0158.
- [21] D. Lauria and S. Quaia, “An investigation on line loadability increase with high temperature conductors,” Jun. 2017. Accessed: Jun. 16, 2022. [Online]. Available: <http://dx.doi.org/10.1109/iccep.2017.8004757>
- [22] S. Nuchprayoon and A. Chaichana, “Performance Comparison of Using ACSR and HTLS Conductors for Current Uprating of 230-kV Overhead Transmission Lines,” Jun. 2018. Accessed: Jun. 16, 2022. [Online]. Available: <http://dx.doi.org/10.1109/eeeic.2018.8493888>
- [23] D. H. Waters, J. Hoffman, E. Hakansson, and M. Kumosa, “Low-velocity impact to transmission line conductors,” *International Journal of Impact Engineering*, vol. 106, pp. 64–72, Aug. 2017, doi: 10.1016/j.ijimpeng.2017.03.010.
- [24] E. K1st1, “Kompozit 1zlu al1miny1m iletkenlerin (ACCC) 1retilmesi ve iletkenliđinin y1kseltilmesi i1in yapılan 1alıřmalar,” <http://openaccess.iste.edu.tr/xmlui/bitstream/handle/20.500.12508/1363/ebrukisti.pdf?sequence=1&isAllowed=y>

- [25] H. B. D. Yasaranga, “Techno economic analysis of the use of high temperature low sag (HTLS) conductors in the Sri Lanka’s transmission system,” <https://uom.lk/sites/default/files/elect/files/14.pdf>
- [26] TEİAŞ-MYD/2005-020.0, “Çelik özlü alüminyum iletkenler teknik şartnamesi,” <https://webim.teias.gov.tr/file/233edf5a-54a1-443c-999d-d92baafe586d?download>
- [27] S. Ay, “Enerji iletim hatları: Cilt 1 İletkenlerin mekanik hesaplamaları,” Efe Akademi Yayınları
- [28] ZHONG Fusheng, YAN Hengmei, LI Liping, JIANG Yong, YAO Yi, DENG Xuejian 2007 Community Structure and Diversity of Birds on East Dongting Lake Wetland of Hunan Province [J] Chinese Journal of Ecology 26(12) 1959-1968
- [29] N C Mavrikakis et al. 2018 Evaluation of the Damage Caused by Bird Pecking Activity along Composite High Voltage Insulators IEEE International Conference on High Voltage Engineering and Applications (ICHVE), Athens Greece, September 2018
- [30] DING Wei, ZHOU Fangron 2015 Analysis and Operation Suggestions on Birds Trouble Trip for Yunnan Power Grid Transmission Line [J] Yunnan Electric Power 43(5) 29-31
- [31] WANG Feng, HUANG Fuyong, ZENG Hao, PENG Bo, WANG Cheng 2011 Analysis and Prevention of Bird Hazard Barriers on Transmission Line in Hunan Province [J] High Voltage Apparatus 47(10) 97-101
- [32] Loschi, Hermes Jose & León, Julio & Iano, Yuzo & Filho, Ernesto & Conte, Fabrizzio & Lustosa, Telmo & Freitas, Priscila. (2015). Energy Efficiency in Smart Grid: A Prospective Study on Energy Management Systems. Smart Grid and Renewable Energy. 6. 250-259. 10.4236/sgre.2015.68021.
- [33] Faruqui, Ahmad & Arritt, Kevin & Sergici, Sanem. (2017). The impact of advanced metering infrastructure on energy conservation: A case study of two utilities. The Electricity Journal. 30. 56-63. 10.1016/j.tej.2017.03.006.

[34] Energy, E. C. (2023, December 6). *The Impact of Internet of Things on Energy Efficiency*. Energy5. <https://energy5.com/the-impact-of-internet-of-things-on-energy-efficiency>