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Web page: www.itegam-jetia.org
Email: editor@itegam-jetia.org
Galileo Institute of Technology and Education of the Amazon (ITEGAM).

Joaquim Nabuco Avenue, No. 1950. Center. Manaus, Amazonas. Brazil.
Zip Code: 69020-031. Phone: (92) 3584-6145.

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RESEARCH ARTICLE OPEN ACCESS

SWOT ANALYSIS OF HALFETI'S RURAL TOURISM POTENTIAL IN THE CONTEXT OF RURAL DEVELOPMENT

Tahir Demir[1], Gönül Sevinç[*2] and Mehmet Reşit Sevinç[3]

[1, 2, 3] Department of Agricultural Economics, Faculty of Agriculture, Harran University. Sanlıurfa, Turkey.

[1] http://orcid.org/0000-0002-2714-1415, [2] http://orcid.org/0000-0001-6322-8844, [3] http://orcid.org/0000-0002-0617-7822

Email: t.demir@harran.edu.tr ,*gsevinc@harran.edu.tr, rsevinc@harran.edu.tr

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ABSTRACT

Halfeti district, located in the southeast of Turkey, is a destination area with tourism potential with its natural beauties, ruins reflecting historical, religious and cultural heritage, and endemic plant and animal existence. With the Birecik dam starting to collect water, the flooded rural settlement areas have become interesting and the tourism destination value of Halfeti district has further increased. Halfeti's tourism value continues to increase day by day after it was included in the Cittaslow network in 2013. Local community, who earned income only through animal and plant production in the past, have gone into rural tourism activities with these changes in Halfeti district, and Halfeti has taken a special place among rural tourism destination areas today. In this study, the rural tourism potential of Halfeti district was investigated in the context of rural development. In the study, SWOT analysis was conducted using primary data. As a result of the SWOT analysis, it was determined that the strengths of Halfeti district in terms of rural tourism potential are greater than its weaknesses. In addition, suggestions are offered for using Halfeti's rural tourism potential in ensuring rural development.

I. INTRODUCTION

The countries' struggle for full political independence, which started after the Second World War and continues today, essentially turns into a struggle for economic development. In order to win the battle successfully, countries have sought development policies appropriate to their structural situation, potential and internal dynamics. [1]–[4]. In the same period, it was thought that structural transformation and development was only possible with the support of political power or governments. [1], [5], [6]. Today, development has become an approach that includes positive change not only in the economic sense but also in the social, cultural and political sense. The development is essentially that is provided the improvement positively as materially and morally in social life by the change of the political, social, cultural and economic structure. In this way, there will ultimately be a positive change in the level of social welfare [7], [8].

The part of development that concerns rural life is referred to as "rural development". Rural living area is all the village settlements within the borders of a country. and people living in these settlements constitute the rural population [9]. The qualifications determined by the State Planning Organization of the Republic of Türkiye (SPO) are very important in understanding the characteristics of rural areas and the rural population. According to SPO, these places that "economic activities are predominantly based on the evaluation of natural resources; face-to-face relationships are relatively more common, living rules are largely shaped by traditions and customs; technical and technological developments and economic, social and cultural developments occur more slowly and delayed" are rural areas. [10].

Development in rural living areas, or simply rural development is "the process of combining the efforts of small communities to improve their economic, social and cultural conditions with the efforts of the state in this regard, integrating these communities into the whole nation and ensuring their full contribution to national development efforts" [11], [12]. At the same time, rural development are whole of efforts towards to increase the income and welfare levels of rural communities by

enabling them to produce in a way that will change positively their socio-economic, political and cultural structure, to eliminate existing inequalities and to establish a physical and social infrastructure in rural areas that is similar to urban areas. However, it is important that these efforts ensure sustainability. For this reason, the environmental, sociological and economic sustainability of rural living areas must be guaranteed. Therefore, activities for rural development should be planned within this framework [13]-[16].

Rural development is also of great importance for the general development of countries. Because approximately 70% of the world's poor population lives in rural areas. For this reason, rural development efforts and policies to be implemented to eliminate rural poverty will indirectly bring about the development of the country [17]–[22].

In this study, primarily the relationship between rural development and rural tourism is discussed. In this context, the rural tourism potential of Halfeti district of Şanlıurfa province in the context of rural development was investigated, a SWOT analysis was made regarding this potential and suggestions were offered.

II. THEORETICAL REFERENCE

II.1 TOURISM AND RURAL TOURISM

Primitive man traveled for protection, to hunt for food and clothing, and to satisfy his sense of curiosity. This travel process was sometimes short distances and sometimes long distances [23]. These travels are activities that correspond to today's tourism concept. Therefore, it would not be wrong to say that tourism is one of the first activities that are mandatory to meet the needs of human beings.

If we were to make a general definition, tourism is the travel and return of people to some sights in a circular motion for business or entertainment purposes [24], [25]. The World Tourism Organization (UNWTO) considers and defines the concept of tourism as a way of going on holiday. According to the definition, tourism includes activities where a person travels and stays in a place outside his/her normal environment for business, pleasure, visiting friends and relatives or for other purposes, and goes to another place of his/her choice for a period not exceeding one year [26]. Today, tourism has grown significantly both economically and socially [23], [27]. In recent years, the fastest growing economic sector in most countries has been the services sector. In some of these countries, the share of the travel and tourism sector in the services sector has reached a significant level. [23], [28], [29].

The development of tourism, in a way, depends on the diversity of tourism supply. The emergence of different demands of those participating in international tourism movements, especially in recent years, is due to the great diversity of tourism supply [30]. The main markets for tourism activities are those with highly developed and urbanized areas. Many living in these areas want to escape modern urban and suburban environments and visit simpler, less developed areas [31]. Recently, tourists' interest has begun to focus on alternative tourism types rather than sea, sand and sun-oriented tourism [30]. People find solutions to problems such as monotony, decrease in human relations, and melancholy caused by urban life by participating in aggregate or alternative tourism activities, where they can have the opportunity to live in a different environment for a short time and even fulfill their longing for rural life [32]. Rural tourism offers an ideal alternative for tourists who are in such search [31], [33].

Seeing the natural beauties of rural areas, meeting with people from different cultures, participating in activities specific to the rural area, and integrating with nature and the environment constitute the scope of rural tourism, which is one of the alternative tourism types. Rural tourism is defined as a type of tourism in which people go to a rural settlement in order to relax in natural environments and be together with different cultures, stay there and watch or participate in activities specific to that region [34]–[36].

The term rural tourism has a wide range and covers all entertainment and recreation activities in rural areas. According to [37], rural tourism includes orchards, farms, culture, life, scenic areas, religious activities, food and air tourism in rural areas [37]. Rural tourism has dimensions of rural production, rural life and rural ecology. Production dimension agricultural activity-oriented tourism (agro tourism or hobby agricultural activities); the life dimension includes rural cultural activities (cultural and historical tourism, museum tourism) and the ecological dimension includes nature-oriented recreational activities (nature tourism, agro-tourism, green or eco tourism) [38].

[39] defined rural tourism as the act of leaving the urban environment and traveling to rural areas. The purpose of doing this is to discover and enjoy the natural beauties, agricultural diversity, history and cultural richness of small towns; is to get away from the pressure of urban life in order to have pleasant experiences and improve the quality of life [26], [39]. According to [31], rural tourism requires location in rural areas, functionally rural businesses and institutions established on a rural scale, and a lifestyle with a traditional character; there must be situations that represent a complex form in terms of rural environment, economy, history and location [31]. According to [40], rural tourism is functionally rural and offers tourists opportunities to directly experience, have fun and learn about unique cultural, natural and historical attractions and activities offered by rural local communities in cooperation with businesses and the public to provide socio-economic benefits without destroying the environment [40].

II.2 RELATIONSHIP BETWEEN RURAL TOURISM AND RURAL DEVELOPMENT

Tourism has direct impacts on national income for all tourist destinations. It creates business opportunities, industries and various investments to serve and elevate the performance and culture of nations, while also offering the opportunity to promote their history, civilization and traditions. As the leading international organization in the field of tourism, UNWTO promotes tourism as a driver of economic growth, inclusive development and environmental sustainability [26].

The century we live in is marked by rural development-oriented approaches that encourage quality, diverse, innovative and environmentally friendly production, contribute to the living standards of producers and contribute to the development of the rural economy. Rural development activates and develops non-agricultural sectors by providing direct added value and income increase to production. In this context, the rural tourism sector is one of the strongest investment areas with the highest potential and claim [41]. There is a direct relationship between rural development and rural tourism. Rural tourism is a symbol of success in non-agricultural diversification in rural areas [42].

Rural tourism is seen as an important element in terms of diversifying the rural economy, creating a new perspective for the people living in rural areas, increasing job opportunities, balancing the income level, preventing migration in rural areas, creating

finance for the protection of nature and ensuring regional development. Successful rural tourism practices enable local people, especially those engaged in agriculture, to earn additional income, increase their level of welfare and share their cultural riches. [43]–[45].

The development of tourist destinations is done by taking into account the tourist attraction potential of the region. In development, the local community is considered an active subject, not a passive one. Therefore, the local community is the organizer and actor in the destination where tourism activities are carried out. This makes the local community an integral part of rural tourism with different cultural characteristics [46]. According to [47], there are five reasons why policy makers and implementers should intervene in the development of rural tourism; these are the protection of potentially attractive areas, modernization of supply structures, marketing, education and expansion of opportunities for participation in rural tourism [47], [48]. If these elements are provided by policy makers and implementers, the probability of success in social development through rural tourism, and therefore in rural development, which is the main goal, is much higher.

II.3 RURAL TOURISM POTENTIAL OF HALFETİ

Halfeti, which is affiliated with Şanlıurfa province, is a district approximately 120 km away from Şanlıurfa city center and approximately 90 km away from Gaziantep city center. Today, Halfeti district has two separate settlements, old and new. With the start of water collection in Birecik Dam in 2000, the old Halfeti, which was established in a plain area, was flooded. Therefore, the old Halfeti settlement area was moved to the new Halfeti district, which was established in the area known as Kara Otlak (Figure 1) [49]–[51].

The main source of income of Halfeti district until 2000 was agricultural activities. After this date, since some of the agricultural areas were submerged under the dam waters, there was a decrease in agricultural activities and agriculture-based economic income [49], [52]. Although agriculture and animal husbandry still constitute the economic life in the district, the natural beauties, cultural and historical sites of the old Halfeti settlement area, which is under water, have led to the emergence of active rural tourism activities today [25], [49], [52]. Today, tourism activities, which started with boat trips in the old Halfeti settlement area, are expanding the range of products and services in the name of rural tourism with the inclusion of different social and cultural activities day by day. The natural, historical and cultural values that Halfeti has and that can contribute to its rural tourism potential are discussed separately below and brief information about them is given.

Figure 1: Halfeti.
Source: [51].

The "Cittaslow" movement, initiated in 1999 by Paolo Saturnini, mayor of Greve, Chianti, Italy, emerged as an alternative movement against the excessive consumption, disrespect for natural resources and unsustainable growth models of capitalist societies created by the Industrial Revolution.. Today, it has become a wide network including 291 cities in 33 countries. 22 cities in Türkiye are included in the Cittaslow network, and Halfeti's participation in the Citaslow network took place in 2013. Halfeti is the ninth city in Türkiye to join the Cittaslow network and is the only city in the Southeastern Anatolia Region (Figure 2-3) [53]–[57].

Figure 2: Cittaslow Halfeti 1.
Source: [53].

Figure 3: Cittaslow Halfeti 2.
Source: [56].

After collecting water for the Birecik Dam, many rural settlements and buildings on the banks of the Euphrates River in Halfeti rural area were flooded. Savaşan Village, Çekem Village and Eren Village in Halfeti are examples of these. When these residential areas were flooded, very different and interesting images emerged. Today, trips to these areas are organized by boats departing from Halfeti. Visitors take photographs in these areas with interesting views. Additionally, cafes and restaurants run by local people living in these areas offer services to visitors. On the other hand, recreation areas have been created so that people who come in groups can rest and picnic in these areas. (Figure 4-5) [25], [58].

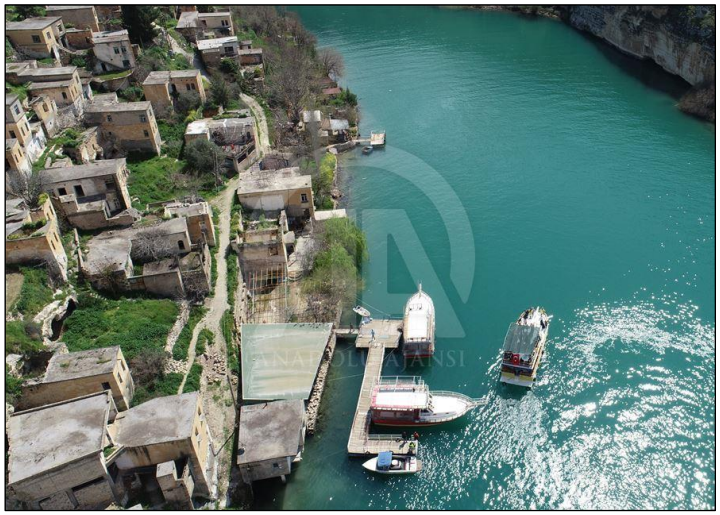

Figure 4: The Savaşan Village of Halfeti District 1.
Source:[58].

Figure 5: The Savaşan Village of Halfeti District 2.
Source:[58].

Figure 6: Rumkale 1.
Source: [58].

Rumkale, which is on the route of boat trips organized in Halfeti, is at the intersection of the Euphrates River and the Merziman Stream. It is located on a high hill surrounded by a steep rocky structure. Rumkale was built on an area of approximately 3500 square meters with cut stones in harmony with nature. Rumkale, built with a rectangular plan, has seven bastions carved by human hands and many battlements-shaped windows in the north. The architectural ruins in Rumkale have Late Roman and Mediaeval character. Among the structures that can be seen in the castle today are St. Nerses Church, Barşavma Monastery, many building ruins, water cisterns, wells and moats. This settlement plays an important role in the history of Christianity, as Yohannes, one of the apostles of Jesus, came to Rumkale, settled there and spread the Christianity religion here during the Roman Period. Today, Rumkale has taken the form of a peninsula surrounded by water after the Birecik Dam became operational and retained water (Figure 6-7) [59], [60].

Figure 7: Rumkale 2.
Source: [59].

The suspension bridge, known as The Halfeti Neck among local people, was built by the Halfeti District Governorate. The completion date of the bridge is 2012. The suspension bridge connects Rüştiye neighborhood, formerly known as old Halfeti, and Başbostan neighborhood. The suspension bridge provides the opportunity to walk to the old cemetery area, pistachio gardens, water sports center and floating pool facilities, which were previously accessible by boat. The bridge located at the entrance of Değirmendere Valley is also a place frequently used by photographers and those who want to take photos. (Figure 8) [61].

Figure 8: The Halfeti Neck.
Source: [61].

Located in the old settlement area of Halfeti district, the Ulu Mosque was built in 1844 and has the characteristics of the Ottoman architecture of its period. As the Birecik Dam became active, 40 cm of the mosque was submerged in 2002 [62]. With this feature, the Ulu Mosque has found its place in the list of places to see and visit in Halfeti (Figure 9).

Figure 9: The Grand Mosque.
Source: [61].

The Kantarma Inn, dating back to the Roman Period of the fifth-sixth century AD, located in Kalkan Village on the Yukarı Göklü-Yaylak road in Halfeti district, is a registered cultural heritage. This historical building remains has survived today with four round arches ordered in three rows parallel to each other in the north-south direction. It has a mixed type and rectangular architecture. The absence of a cooker, manger or similar elements indicating that the building was an inn makes it difficult to state a definitive opinion about its nature, but it brings to mind that it may have been a granary. Properly cut large stones were used in the building ruins, which had no decorative elements other than the molding on the pillar capitals (Figure 10) [61], [63].

Figure 10: Kantarma Inn.
Source: [61].

Nurhut Church, located in the north of Gürkuyu (Nurhut) village in Halfeti district center, is a building that dates back to the fifth-sixth century AD and is one of our (Byzantine) registered cultural heritage. The church was built of ashlar stone work and has a rectangular plan in the east-west direction. On the west-facing entrance façade, there is a rectangular entrance door of which surrounding decorated with moldings, with a plain lintel. A holy rood motif is engraved in a circular rosette in the middle of the lintel. A relieving arch was made on the lintel by carving a single block of stone. There are three round-arched and rectangular-shaped windows on this frontal. It is understood that the building with a triangular pediment above the windows is covered with a roof. The moulding apse arch on the eastern frontal of the building is still standing, but its wall has been destroyed. It is understood from the foundation traces that the apse was round (Figure 11) [61], [63].

Figure 11: Nuhrut Church.
Source: [61].

Değirmendere Stream, located within the borders of Halfeti, rises from the mountains above old Halfeti and flows into the Euphrates River. Değirmendere Valley; It covers an area of approximately two kilometers on the flow path of the Değirmendere Stream and northeast of Halfeti. The valley is home to many endemic plant and living species. It also has a very suitable structure for hiking routes. There are many natural pools, historical water channels, grain mills and hand-carved or naturally formed caves on the walking route (Figure 12-13) [64], [65].

Figure 12: Değirmendere Valley.
Source: [64].

Figure 13: Değirmendere hand carved caves.
Source: [65].

Halfeti Black Rose, which is also known by names such as "Arabic bride, Arabic beauty, Arabic girl, Mesopotamian rose, Flat rose", is an endemic rose variety that grows only in Halfeti in the world. Although the rose is completely black, it is a scented rose that can also have a dark red color close to black. The origin of Black Rose dates back to the French rose breeder Guillot in 1859. Black Rose, growed by Guillot, "14. Louis" is a type of rose. However, there is no definitive information about how it came to Türkiye, especially Halfeti [49], [66]–[68]. Another feature of Black Rose is that when it is taken both as branches and seeds to a place other than Halfeti, its color changes and loses its properties. This is a situation that identifies Black Rose and Halfeti. Therefore, it is used extensively by the local people in the promotion of Halfeti and becomes an source of income (Figure 14).

Figure 14: Halfeti Black Rose (R. Odorata Louis XIV).
Source: [68].

The Euphrates turtle is an endemic species that lives in the Euphrates and Tigris Rivers and their tributaries in Turkey. They generally feed by consuming aquatic animals. The areas around the Euphrates River and the islands close to the shore are important habitats for the Euphrates turtle. The species is evaluated as endangered (EN) according to the criteria of the International Union for Conservation of Nature and Natural Resources (IUCN) (Figure 15) [61], [69].

Figure 15 Euphrates Turtle (Rafetus euphraticus).
Source: [61].

The Desert Varan (V. griseus) is an animal distinguished by its size. Its length exceeds 1 meter (130 cm). Color may vary depending on habitat. The dorsal side is yellowish-orange grey. The neck is quite long compared to the body. Its mouth has strong teeth and a long split tongue. In other words, their tongues are long and forked, like a snake's tongue, and they also perform the function of smelling with their tongues. When they feel in danger, they can inflate their neck sacs to scare the other animal. Capturing, killing or harming the species is strictly prohibited. The Desert Varan species Conservation Action Plan has been prepared by the General Directorate of Nature Conservation and National Parks and monitoring efforts are continuing. Şanlıurfa Birecik Steppes, which is one of the most natural areas of Turkey's steppe ecosystems and provides shelter for many endemic animal species, has also been declared a Wildlife Development Area and contributes to the protection of the species (Figure 16) [61], [70].

Figure 16: Desert Varan (V. griseus).
Source: [61].

Located on the banks of the Euphrates River, Halfeti is located in a rich basin for bird watchers and photographers in terms of bird diversity. The bald ibis (Geronticus eremita) is among the most well-known species of these birds in the world (Figure 17). Bald Ibis is a species considered extinct in nature in Turkey. Production is carried out at the Bald Ibis Breeding Station in Birecik, Şanlıurfa, and as of 2021, there are 278 individuals in the production station. Bald ibises, which are released during the breeding period, are taken back into cages in July [61], [71].

Figure 17: Bald Ibis (Geronticus eremita).
Source: [61].

III. MATERIALS AND METHODS

In this study, it is aimed to determine the rural tourism potential of Halfeti district in the context of rural development. In this context, literature review was made on Halfeti district and individual interviews and observations were made in Halfeti district, which is the research area, to determine the current situation. The main material of the study consists of primary data. Formal interview forms were used to collect primary data. Interviews were conducted with local people, local businesses, employees of public institutions operating in the district and individuals visiting for touristic purposes. No sample calculation was made for the interviews, and as many individuals as possible from all walks of life were reached by using the convenience sampling method. A total of 79 people were interviewed in the field, including 21 local people, 13 local business owners, 8 public institution employees and 37 tourists. Within the framework of the information obtained, the rural tourism potential of Halfeti district was revealed by SWOT analysis.

SWOT analysis is a strategic technique used to determine the strengths and weaknesses of an issue and the opportunities and threats to be encountered. SWOT analysis guides to identify these four characteristics and thus develop a more comprehensive awareness of the situation, which helps in strategic decision making [72], [73]. The SWOT method was originally developed for business and industry. However, today it is used in the same way in society, health, development, tourism, education and even personal development studies. [72]. SWOT analysis regarding tourism destination areas; It aims to determine and develop the ability to plan for the use of the resource values of the area, to produce strategies, to organize areas and uses, and even to ensure sustainability [73]–[75].

IV. RESULTS AND DISCUSSIONS

The SWOT analysis results prepared using primary data obtained from field studies are given in Table 1.

Table 1: SWOT analysis results.

Strengths	**Opportunities**
• Halfeti becoming a member of Cittaslow, • The region has an unspoilt natural appearance, • The part of the area under the dam water has a different and interesting appearance, • Having a culture and structure suitable for nature tourism, • The presence of many valuable historical and religious ruins in the area (Rumkale, St. Nerses Church, Barşavma Monastery, Norhut Church, Kantarma Inn and Ulu Mosque, etc.),Endemik türler açısından (bitki ve hayvan) önemli bir tabiat alanına sahip olması, • Local people are hospitable and willing to engage in rural tourism activities, • Various festivals (fruit-food festival, water sports festival, fragrance festival) and feasts started to be held, • A department that trains qualified personnel for the tourism sector is active in the field within Harran University.	• In recent years, interest in rural tourism has begun to increase as an alternative to traditional tourism. • Increasing the quality of the rural workforce by improving the professional knowledge and skills of individuals employed in rural tourism through different training programs, • Rural tourism creates a source of income for those living in the district, • Making planned and more professional investments by using support, incentives and grants from national and international institutions for rural tourism investments, • Minimizing the income and development gap between rural and urban areas, • Eliminating the physical infrastructure deficiency of rural areas, • Ensuring socio-economic development of the district by preventing migration to cities, • Increasing the foreign exchange earnings of the area and therefore the country, thanks to tourists coming from abroad.
Weakness	**Threats**
• Local people do not have sufficient knowledge and equipment regarding the development of rural tourism, • The investment budget and promotion for the development of rural tourism in the district is not at the desired level, • Failure to make regular plans for the active use of rural tourism areas, • Tent and caravan camping areas are not active, • Environmental pollution due to lack of personnel for cleaning public places such as picnic and excursion areas, • Tourists do not find the service quality and prices offered by different businesses to be standard, • Continuing migration from district to city and/or abroad,	• The socio-cultural structure of the tourist area begins to deteriorate over time, • Buildings built or likely to be built in the surrounding area are not constructed in accordance with the architectural structure of the area, • Natural beauties are under threat due to excessive visitor demand, • Insufficiency of qualified personnel due to the increase in rural tourism potential and the migration of the young population, • Traditional culture weakens and/or begins to deteriorate over time,

Source: Authors, (2024).

Looking at the SWOT analysis results, it can be said that the strengths of Halfeti district in terms of rural tourism potential are greater than its weaknesses. When the strengths are examined, we can say that Halfeti's being a member of Cittaslow and having an unspoiled natural appearance despite a part of the district being flooded are its strongest aspects in terms of rural tourism. The fact that the district has an unspoilt natural appearance makes the region more attractive and significantly affects the number of tourists coming to visit. Being the district a member of Cittaslow makes it known in the national and international arena. The presence of many valuable historical and religious ruins in the area offers tourists who visit the region the opportunity to see different tourist

attractions. The presence of Halfeti Vocational High School affiliated with Harran University here, the activities actively carried out by the Department of Tourism, Travel and Entertainment Services at the school, and the organization of various festivals and organizations together with various public institutions and civil society organizations contribute to tourism. Halfeti Ulu Mosque and Savaşan Village Mosque, located in the old town center, created a different appearance after being flooded after the Birecik Dam was built, offering tourists the opportunity to see both the natural view and the flooded areas with boat tours lasting about an hour. In addition to this, the endemic plant and animal species that grow and live only in this area in Turkey make the region very attractive for tourists. The fact that the local people are hospitable and willing to engage in rural tourism activities is one of the strengths of the district regarding its rural tourism potential. The strengths that emerged as a result of the analysis show that the rural tourism potential and therefore the rural development potential of Halfeti district is quite high.

When the weaknesses of rural tourism in the district are examined; the fact that the local people do not have sufficient knowledge and equipment in terms of the development of rural tourism may cause them not to be able to use the tourism potential of the district efficiently and to establish positive relationships with the visitors, and this situation negatively affects rural tourism and rural development. There is not enough investment budget allocated for the development of rural tourism in the district. Investments made individually have not professional quality and proceed in an unplanned manner. In addition, it can be said that the promotion of the district is not carried out at the desired level by both the local government and the relevant institutions. Considering that the majority of the visitors interviewed in the field research had visited the district before and brought their relatives to show them around; It is concluded that Halfeti district is not sufficiently promoted as a tourism area. Failure to adequately promote the natural, cultural and historical values of Halfeti district in terms of rural tourism prevents the desired number of visitors from being reached. In addition, the lack of creation of destinations and activity areas, which are very important in rural tourism, such as tent and caravan camping areas, water sports, mountain bike trails and nature hiking trails, negatively affects the number of visitors. This situation causes those who visit Halfeti district to be content with day trips and not to stay. Due to the lack of planning for the development of rural tourism, sufficient personnel employment in the area could not be provided. Therefore, serious problems arise regarding the cleanliness of the area. In addition, due to the unprofessional management approach, there is no standard practice in the service quality and prices offered. This situation was frequently mentioned by visitors during field studies. Lack of planning and professionalism restricts the rural tourism service period in Halfeti district to certain periods, that is, causes businesses to close, especially in winter. However, the greatest success of rural tourism activities can be measured by their spread to all periods of the year. It is a type of activity that must be continuous. Since rural tourism activities are intermittent and seasonal, the businesses in the region operate without continuity, causing the young population to migrate from the district.

When the opportunities in terms of rural tourism potential are examined, the increasing interest in rural tourism as an alternative to traditional tourism in recent years will increase the number of tourism activities in the district and increase the importance given to tourism activities. The fact that rural tourism creates a new source of income for the local people living in the district, will increase the quality in the service sector and enable the work done to become a professional profession. Today, investment supports and grants for the development of rural tourism are an important implementation for sustainable development and rural development. There are many national and international public institutions and civil society organizations that provide this support and grants. If local people benefit from these supports and grants, it will ensure that rural tourism investments in Halfeti district are made more planned and professionally. Thus, steps will be taken towards sustainable local development goals, which is one of the most important issues in rural development. Thanks to the investments made for the development of rural tourism in Halfeti district, the lack of physical infrastructure will be eliminated, the development gap between rural and urban areas will be minimized, and migration to cities will decrease due to the socio-economic development of the local peopleTherefore, the rural development goals aimed at both local and national levels will be achieved.

The most important threat that Halfeti district faces in terms of rural tourism potential is the deterioration of the socio-cultural structure of the region over time. At the same time, with the increasing tourism potential, it is inevitable that construction in the area will increase. If the buildings built or planned to be built in the area are not constructed in accordance with the architectural structure of the area, it will disrupt the natural structure of Halfeti district in terms of rural tourism and thus negatively affect its attractiveness. When excessive visitor demand is added to this situation, there will be a danger for the natural environment where endemic plants and animals live. Unpreventable young population migration is a threat that reveals the problem of supplying qualified personnel and negatively affects the rural tourism potential of Halfeti district. Finally, the threat of the traditional culture weakening and/or deteriorating over time, which is inevitable for rural tourism areas, is also valid in Halfeti district.

V. CONCLUSIONS

Halfeti district is a destination area with tourism potential with its natural beauties, ruins reflecting historical, religious and cultural heritage, and endemic plant and animal existence. With the Birecik dam starting to collect water, the flooded rural residential areas have become interesting and the tourism destination value of Halfeti district has further increased. Since Halfeti was included in the Cittaslow network in 2013, its tourism value continues to increase day by day. Local people, who earned income only through animal and plant production in the past, started rural tourism activities with these changes in Halfeti district, and Halfeti has found a special place among rural tourism destination areas today.

In this study, the rural tourism potential of Halfeti district was investigated within the framework of rural development and its current situation was revealed with SWOT analysis. As a result of the SWOT analysis, what needs to be done to ensure rural development by using rural tourism opportunities in Halfeti district is stated below.

Local people in the district and tourist business owners, most of whom are local people, are very pleased with tourism activities and having part in these activities. However, they do not have sufficient experience and knowledge in the tourism-related service sector. For this reason, local people and business owners should be informed about rural development and rural tourism, and rural tourism should be developed by creating various training programs in cooperation with local governments and universities.

Although the number of accommodation establishments serving in the district is sufficient, it has been determined that some facilities built in recent years are not suitable for the natural and architectural structure of the region, and local people and visitors are quite disturbed in this regard. The most important threats that arise in rural tourism areas are the deterioration of the local texture, natural beauties and culture and their disappearance over time. Authorized units need to be sensitive about this issue and fulfill their responsibilities without loss of time.

Tourists who come to visit the district meet their accommodation needs in nearby provinces such as Şanlıurfa and Gaziantep after day trips. The most important reason for this situation is that the service quality and service range of local accommodation facilities are not at the desired level and the guests think that the prices they pay for the service received are high. Accommodation facilities need professional support in order to increase their service quality and make a difference in the services provided. In this regard, support can be obtained from local governments and the relevant unit of the university operating in the district.

Individuals who want to stay in rural areas are individuals who want to be alone with nature and want to get away from the noise of the city and traditional tourism activities. These individuals like to meet their accommodation needs in tents or caravan camping areas instead of hotels or hostels. In Halfeti district, there is no active camping area with prepared infrastructure (electricity, drinking water, waste water disposal area, etc.), security ensured and to meet the need for alternative accommodation. The existence of such a camping area will increase the number of days of stay of visitors, practicapability of tourism activities also in the winter months and the recognition of the district. For this reason, especially the local government and security forces need to take an active role in the camping area and make plans for this purpose.

Although there are active efforts to promote Halfeti district in visual media, it is not enough. Nowadays, social media is much more active and impressive, especially in the promotion of tourism areas. Today, many tour companies organize trips to Halfeti district, and many websites offer accommodation opportunities. However, promotion on social media can be much more effective than these promotional activities. In this regard, local administrations and responsible units should receive support from social media experts (instagram, twitter, you tube, etc.) who engage in national and international activities. This support can be both more cost-effective and more effective than visual media channels.

The most important issue that should not be ignored in rural tourism activities and rural development efforts is the protection of the natural structure and environment. During the field studies, the most common complaints from visitors were about the deterioration of the natural structure and the pollution of the environment. Local governments have a great responsibility to prevent the natural structure from being damaged. On the other hand, due to the large size of the destination area, the number of personnel providing environmental cleaning services is insufficient. Since increasing the number of personnel requires an additional cost for local governments, it may be considered to charge a representative destination area entrance fee to cover this cost. The collected fee will be able to provide a budget for both increasing the number of personnel and carrying out infrastructure works that will not damage the natural structure in the destination area.

On the other hand, visitor density can be prevented by ensuring that only visitors whose main purpose is to visit and stay can enter the area. Today, with a similar practice in many countries, financing has been provided both for the protection of rural tourism destination areas and for investments to increase the value of these areas.

As a result, rural tourism has an important place in ensuring rural development in Halfeti district. There are sufficient resources for rural tourism and therefore rural development. In order to use these resources efficiently, the threats revealed in the SWOT analysis must be eliminated and appropriate solutions must be produced for the weaknesses. While making plans and programs for regional tourism, the strengths and weaknesses, opportunities and threats in the SWOT analysis should be taken into account.

VI. AUTHOR'S CONTRIBUTION

Conceptualization: Tahir Demir, Gönül Sevinç and Mehmet Resit Sevinç.
Methodology: Tahir Demir, Gönül Sevinç and Mehmet Resit Sevinç.
Investigation: Tahir Demir, Gönül Sevinç and Mehmet Resit Sevinç.
Discussion of results: Tahir Demir, Gönül Sevinç and Mehmet Resit Sevinç**.**
Writing – Original Draft: Tahir Demir, Gönül Sevinç and Mehmet Resit Sevinç**.**
Writing – Review and Editing: Tahir Demir, Gönül Sevinç and Mehmet Resit Sevinç.
Resources: Tahir Demir, Gönül Sevinç and Mehmet Resit Sevinç.
Supervision: Tahir Demir, Gönül Sevinç and Mehmet Resit Sevinç.
Approval of the final text: Tahir Demir, Gönül Sevinç and Mehmet Resit Sevinç.

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RESEARCH ARTICLE OPEN ACCESS

DETECTION OF TRAFFIC ACCIDENTS USING ARTIFICIAL INTELLIGENCE

Jesus Gerardo Ávila Sánchez[1], Francisco Eneldo López Monteagudo*[2], Francisco Javier Martinez Ruiz[3] and Leticia del Carmen Ríos Rodríguez[4]

[1, 2, 3, 4] Autonomous University of Zacatecas, Av. López Velarde No. 801 CP 98060 Zacatecas, México.

[1] http://orcid.org/0000-0001-8518-2023, [2] http://orcid.org/0000-0001-6082-1546, [3] http://orcid.org/0000-0002-8842-7556, [4] http://orcid.org/0000-0002-1005-020X

Email: jesusw12@gmail.com, *eneldolm@yahoo.com, javier.martinezruiz@uaz.edu.mx, leticia.rios@uaz.edu.mx

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ABSTRACT

This article analyzes different architectures with which a neural network can be developed using computer vision with the objective of detecting traffic accidents. For the development of the software, the Java Script programming language was used, reaching the conclusion that the best architecture to use is a Convolutional Neural Network since it has the capabilities of detecting features within the images. At the same time, a database was developed with the necessary characteristics for the functioning of the neural network.

I. INTRODUCTION

The objective of this research is to propose a database to implement a convolutional neural network trained for the detection of car crashes with a certain degree of effectiveness and with the ability to communicate to emergency services to contribute to saving lives, since as the average speed of vehicle driving increases, it also increases the probability of accidents and the severity of their consequences. Timely access to emergency care after a traffic accident can save lives and reduce the risk of disability among the injured; the key to an effective emergency care system is the establishment of universal access numbers [1].

To build the categories within the database, the data provided by the Ministry of Health of the federal government of Mexico was taken into account; traffic accidents are divided into three large groups. The first of them is the run over, the rollover, leaving the road, the fire and the crash; The second classification is the type of crash within this classification: head-on, reach, side, against the movement and the third classification is directed towards the target of the vehicle in motion [2].

In Mexico, the authorities state that there is a daily average of 9.6 Mexicans killed in traffic accidents and 56.6 injured. They have also recorded that 72% of the reasons why an accident occurs are attributable to the human factor, being the most common causes. incompetence, fatigue and drowsiness, only 14.73% are attributable to vehicle failures, [3].

Currently, the use of unmanned aerial vehicles (UAVs) in civil tasks is common, although the first data known about UAVs dates back to the 1950s and was exclusively in military applications [4]. Currently, with the release of this technology and its low production costs, they are more accessible for scientific development and public safety [5].

In the field of Machine Learning, there are projects aimed at detecting emergencies in traffic accidents, having the capacity to: predict accidents [6], use drones to assist in accident response [7], manage swarms of drones to maintain security in cities [8], image analysis for rescues in places with little or no accessibility [9]. We see that, despite what has been developed, these projects are focused on the ability to directly observe human beings, leaving

aside the capacity of networks to detect the objects involved in the accident, such as cars. On the other hand, in databases for training and emergency detection with neural networks, the importance of progress in specialized databases for object detection with computer vision tools such as the ml5 library has not been considered [10] built with JavaScript and which is built on TensorFlow [11].

II. METHODOLOGY

The structure of the network is defined by the number of layers, the number of neurons in each layer, the degree of connection and the type of connection between neurons. However, the topology of the network depends on the complexity of the problem to be solved.

To develop an artificial neural network, several algorithms are used, of which the majority are based on adjusting the parameters of the network (value of the weights between the connections of neurons) previously designed, therefore, the training process is directly influenced. due to the limitations imposed in the design of the architecture of an artificial neural network (ANN) [12].

In this research, the data to be analyzed (images) were collected from an internet search, divided into a series of categories described by the Secretary of Health of Mexico, which are shown in Table 1.

Table 1: Number of images to train neuron network.

Platform	Category	Number of Images
GOOGLE	Car	1000
	frontal crash	250
	Side crash	250
	rear crash	250
	rollover	250

Source: Authors, (2024).

The general scheme to create the database and to detect traffic accidents with cars involved is based on the random search for images that contain vehicles in good condition, random search for images that contain vehicles involved in accidents, classification of the images collected in training and prediction classes and tests. The images selected to be part of the database must not be processed in advance. Table 2 contains the statistics of the database (set of images) proposed in this article.

Table 2: Database statistics.

Amount	Medium resolution	Maximum resolution	Minimum resolution	Standard deviation	Minimum resolution images	Medium resolution images	Maximum resolution images
2000	257x195p	800x1333p	300x168p	28x39p	458	879	46

Source: Authors, (2024).

The classification and labeling of the set of images, in which there are cars involved in an accident, were classified as follows: the class (accident), and a series of images of cars without apparent error such as the class (car), where the accidents were classified based on apparent external blows to the vehicles and/or situations where the accident is apparently unequivocal, such as an impact, so it must be taken into account that human experience can generate failures in the implementation in an ANN.

In the experiment, the covolutional neural network architecture was used, which is the best option for prediction using this type of data. Likewise, the weights of each neuron will initially be assigned randomly. Tables 3 describe the types of models developed for the experiment.

Table 3: Model configuration.

Model		Dense	Simple Convolutional			Drop-out Convolutional		
Neurons	Entrance	10000	10000					
	Exit	2	2					
Hidden Layers		3	3					
Convolutional Layers		0	3					
Filters		0	32	64	128	32	64	128

Source: Authors, (2024).

The algorithms must have a number of input neurons (10,000) that correspond to each of the 100 x 100 image pixels, and 2 output layers, which belong to the car and accident categories.

The pixel values are within the values 0 to 255 and multiplied by 3 these data are not within the activation threshold of the transfer function, therefore, it is necessary to normalize the data, so that each of The pixels have to go from the aforementioned range to values between 0 and 1.

The experimental configuration was carried out in two phases, in phase 1 three ANN architectures were used, dense, convolutional and drop-out convolutional, in the same way a variation in the dense and CNN2 topologies was used when performing data augmentation, the configuration It is presented in Table 4. In phase 2, prediction tests are carried out (laboratory simulation) as presented in Table 5.

Table 4: Experimental configuration by architecture.

Architecture type	Eras	Supervision in %
Dense	10	100
	50	100
	100	100
CNN	10	100
	50	100
	100	100
CNN Drop-out	10	100
	50	100
	100	100
Dense with Data Augmentation	10	100
	50	100
	100	100
CNN Drop-out with Data Augmentation	10	100
	50	100
	100	100

Source: Authors: (2024).

Table 5: Experimental setup for prediction through laboratory simulation.

Type of incident	Amount of C	Supervision in %
No accident	10	100
	20	100
	30	100
Frontal	10	100
	20	100
	30	100
Side	10	100
	20	100
	30	100
Rear	10	100
	20	100
	30	100
rollover	10	100
	20	100
	30	100

Source: Authors, (2024).

III. RESULTS AND DISCUSSION

To choose the best network architecture, a series of training experiments were carried out with the database using the Google Colab platform [13], TensorBoard [14] was used for graph visualization and data analysis. Microsoft Excel [15] was used. Table 6 shows the experimental results with the different architectures and Table 7 shows the experimental results for different types of classes.

Table 6: Experimental results with different architectures.

Dense architecture					
	Amount	Half	Maximum	Minimum	Deviation Standard
Precision	100	68.25	76.08	57.37	4.786
Loss	100	59.04	67.61	50.29	4.771
Precision Assessment	100	58.51	61.00	55.36	1.225
Loss Assessment	100	72.20	86.86	65.93	5.314
Simple convolutional architecture					
Precision	100	98.56	99.99	67.37	4.45
Loss	100	3.44	56.19	0.72	9.04
Precision Assessment	100	84.14	85.64	77.45	1.19
Loss Assessment	100	122.90	182.16	33.78	37.14
Drop-out convolutional architecture					
Precision	100	97.92	99.72	76.5	4.16
Loss	100	5.31	48.63	0.94	9.04
Precision Assessment	100	84.30	86.48	76.53	1.45

Loss Assessment	100	79.82	130.69	35.33	22.39
Drop-out convolutional architecture with data augmentation					
Precision	100	76.65	81.76	54.18	5.29
Loss	100	47.79	68.68	40.00	6.79
Precision Assessment	100	79.82	86.24	55.64	5.95
Loss Assessment	100	42.63	68.45	31.42	8.54

Source: Authors, (2024).

As seen in Table 6, among the different architectures analyzed, the Drop-out convolutional neural network architecture with data augmentation is the one that presents the best results in prediction.

Table 7: Experiment results for different types of classes.

Experiment	Class	Time (sec)	Total Time (sec))	Average	Maximum	Minimum	Deviation Standard
1	Nothing	30	90	83.8117	93.9335	50.2577	9.2268
	Car	30					
	Accident	30					
2	Car	30	90	88.6343	96.9580	50.1106	8.0948
	Accident	30					
	Nothing	30					
3	Accident	30	90	88.6573	95.9763	52.1264	8.2450
	Nothing	30					
	Car	30					
4	Nothing	30	60	89.0279	97.7199	50.7856	8.5295
	Car	30					
5	Nothing	30	60	89.0732	96.4942	53.3304	7.6006
	Accident	30					
6	Car	30	60	85.5743	94.9029	50.2936	9.1175
	Accident	30					
7	Nothing	30	30	89.5539	97.6704	60.8352	7.6981
8	Car	30	30	86.3457	95.7900	50.0037	10.6814
9	Accident	30	30	86.4051	95.3482	52.5358	8.8555

Source: Authors, (2024).

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III.1 EXPERIMENT 1. NOTHING/CAR/ACCIDENT CLASS

In an experiment with the CLASS NOTHING/CAR/ACCIDENT, the system that contains the neural network was allowed to operate, detecting a series of objects or surfaces that are neither cars nor accidents, immediately afterwards it was allowed to predict cars and ended up detecting accidents, each class was operated for the amount of 60 prediction cycles, the results are shown in the Figure 1.

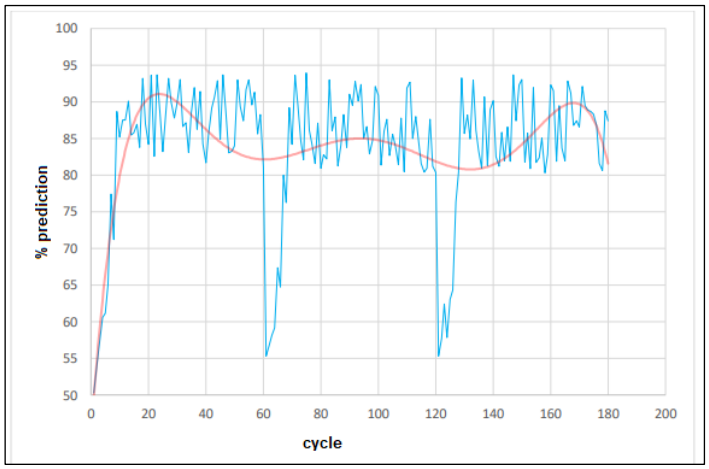

Figure 1: Experiment 1 results.
Source: Authors, (2024).

III.2 EXPERIMENT 2. AUTO/ACCIDENT/NOTHING CLASS

In the experiment with the AUTO/ACCIDENT/NOTHING CLASS, the system was allowed to operate with different cases that included the types of classes in an orderly manner for 60 cycles each and the results shown in Figure 2 were obtained.

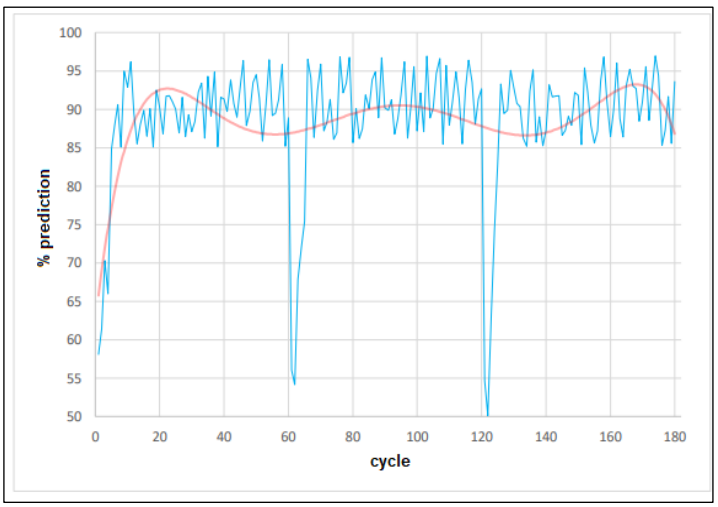

Figure 2: Experiment 2 results.
Source: Authors, (2024).

III.3 EXPERIMENT 3. ACCIDENT/NOTHING/CAR CLASS

In this experiment Class ACCIDENT/NOTHING/AUTO, the system was allowed to operate with 60 cycles per class and the results shown in Figure 3 were obtained.

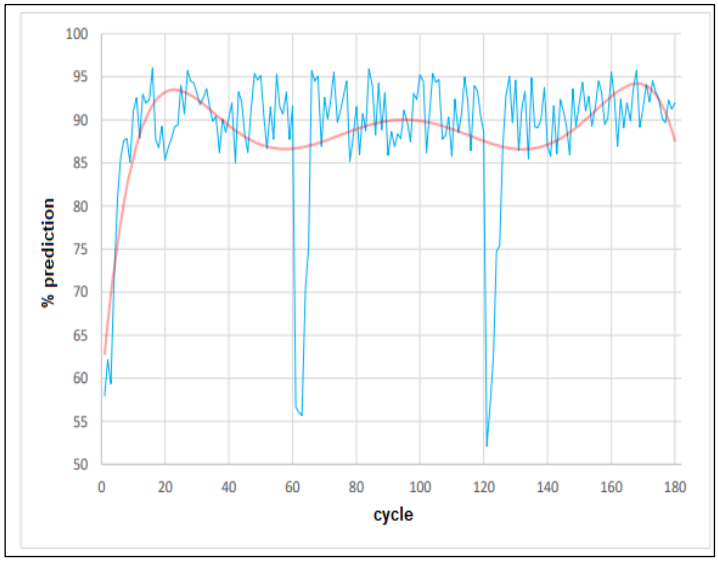

Figure 3: Experiment 3 results.
Source: Authors, (2024).

III.4 EXPERIMENT 4. NOTHING/ACCIDENT CLASS

From this experiment it begins with the combination of classes, in the specific case of this the system was configured for the detection of NOTHING (different objects) and ACCIDENTS for a number of 120 cycles divided into two, 60 cycles for each class. The results are shown in Figure 4.

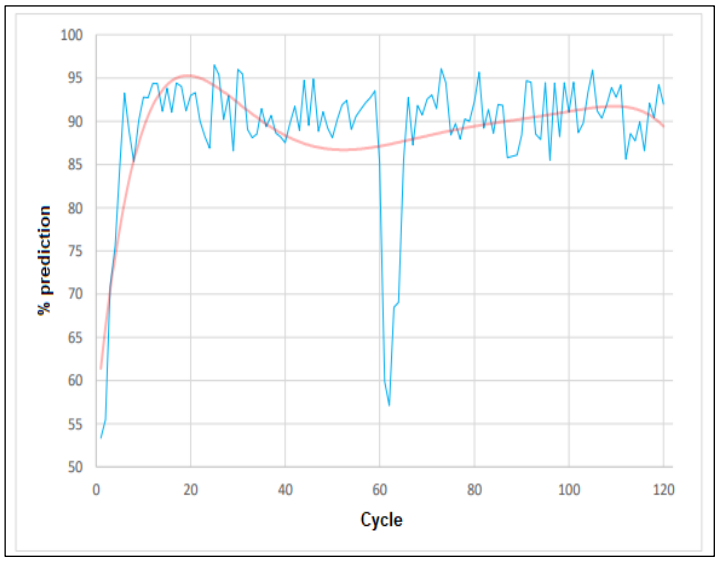

Figure 4: Experiment 4 results.
Source: Authors, (2024).

III.5 EXPERIMENT 5. NADA/AUTO CLASS

In this experiment, the prediction of the NADA and AUTO class is carried out through the system, which was programmed for the number of 120 cycles, divided into two of 60 each, the results are shown in Figure 5.

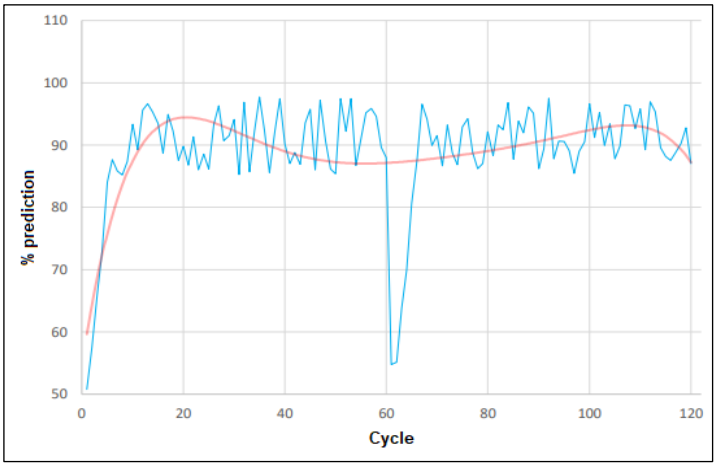

Figure 5: Experiment 5 results.
Source: Authors, (2024).

III.6 EXPERIMENT 6. AUTO/ACCIDENT CLASS

In this experiment, the results obtained by the system are presented after programming them to analyze the AUTO and ACCIDENT classes obtained in a series of 120 cycles divided into 2, 60 for each class, the results are shown in Figure 6.

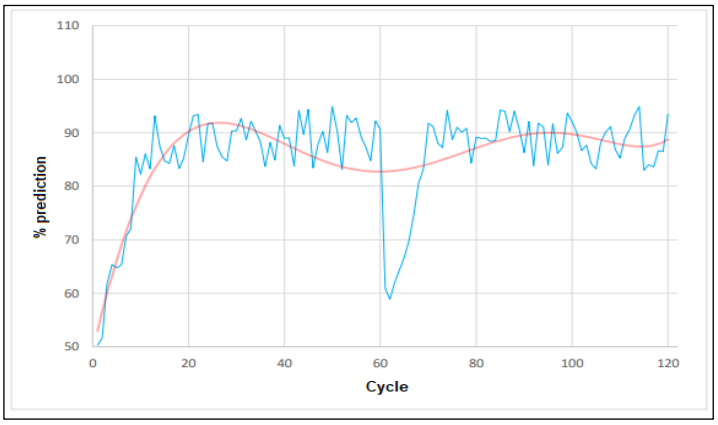

Figure 6: Experiment 6 results.
Source: Authors, (2024).

III.7 EXPERIMENT 7. NOTHING CLASS

In this experiment, a 60-cycle programming was carried out where the network tries to predict the class NOTHING, which includes everything that does not fall into the car and accident classes, the results are shown in Figure 7.

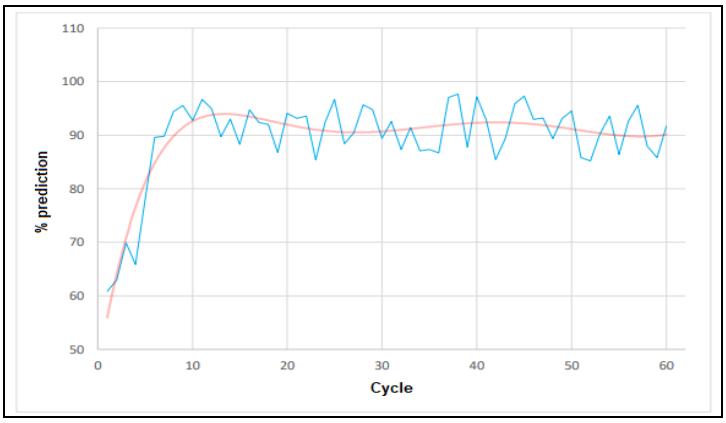

Figure 7: Experiment 7 results.
Source: Authors, (2024).

III.8 EXPERIMENT 8. AUTO CLASS

In this experiment, a series of data is introduced to the network where cars without apparent accident are found, for 60 cycles, obtaining the results shown in Figure 8.

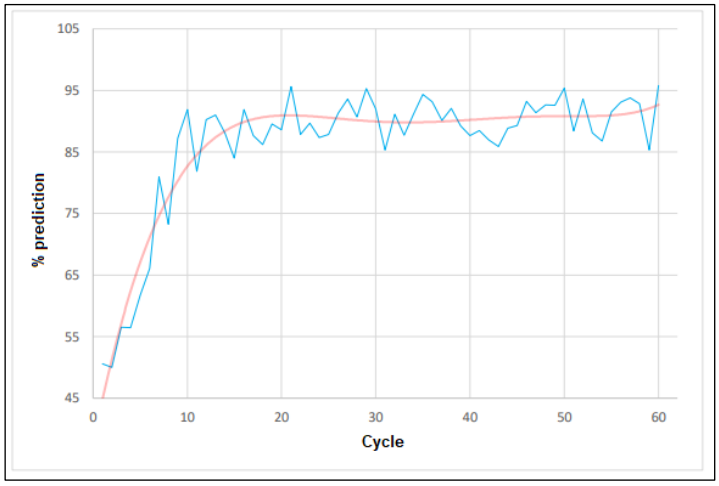

Figure 8: Experiment 8 results.
Source: Authors, (2024).

EXPERIMENT 9. NOTHING CLASS

In this experiment, the results obtained by letting the system analyze a series of data are presented where images of cars involved in apparent accidents are found. The results are shown in Figure 9.

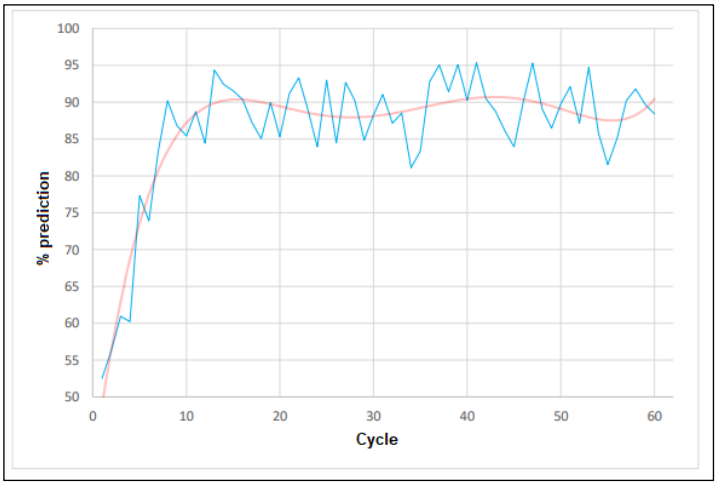

Figure 9: Experiment 9 results.
Source: Authors, (2024).

In the network training stage, a series of open source libraries were used, especially tensorflow [11] specially designed for object detection through computer vision; the neural network was trained for a set of 60 epochs.

In the prediction tests carried out on a number of 100 images divided into 5 categories, the neural network trained with the set of images proposed in contrast to human experience was found, the results are shown in Table 8.

Table 8: Database statistics and prediction average.

Category	Prediction	human experience	Detection Average	Prediction Security
Car	20	20	100%	98.56%
Car and accident	11	20	55%	97.32%
accident	18	20	90%	87.54%
Multiple Accident	5	20	25%	81.42%
Neither Car, nor Sinister	20	20	100%	100%

Source: Authors, (2024).

Using the database, 2000 images were processed using neural networks to detect car accidents. The stopping average represents the number of images detected by the network and the reliability in predicting damaged cars.

IV. CONCLUSIONS

The architecture with which the best results were obtained with an average of 98.56 in the prediction is the simple convolutional, so we selected this architecture, but in it we found overfitting of the data, simply going from a real prediction to the simple learning of the data from the network, this means that when making a simple change in one of the images or the situation where a car or an accident is located, this architecture does not fulfill its purpose. To repair this type of errors, the architecture was modified by going from a simple convolutional neural network to one with drop-out with which the data overfitting error is corrected, sacrificing the prediction average, going from 97.91% to only 76.74%. Overfitting error is eliminated and the accident prediction results correspond to reality within the technological capabilities with which the network training was developed. Likewise, it is observed that the network increases its detection capacity the more cycles it is. trained, observing that at the end of the training, it obtains a capacity of around 86%, which allows us to conclude that with more training cycles the capacity of the network to detect the classes with which it was trained increases. Taking into account the above, a series of experiments was developed with the drop-out convolutional neural network architecture and with data augmentation, which were developed with a simulation in several of the scenarios that could exist in the event of an accident on a road. , from which it was concluded that on a general average the network has the capacity to detect traffic accidents with an average certainty of 87.45% in correspondence with the hypothesis that artificial intelligence is capable of reducing the time for an accident to be attended to.

V. AUTHOR'S CONTRIBUTION

Conceptualization: Francisco Eneldo López Monteagudo, Jesus Gerardo Ávila Sánchez, Francisco Javier Martinez Ruiz, Leticia del Carmen Ríos Rodríguez.
Methodology: Francisco Eneldo López Monteagudo, Jesus Gerardo Ávila Sánchez, Francisco Javier Martinez Ruiz, Leticia del Carmen Ríos Rodríguez.

Discussion of results: Francisco Eneldo López Monteagudo, Jesus Gerardo Ávila Sánchez, Francisco Javier Martinez Ruiz, Leticia del Carmen Ríos Rodríguez.
Writing – Original Draft: Francisco Eneldo López Monteagudo, Jesus Gerardo Ávila Sánchez, Francisco Javier Martinez Ruiz, Leticia del Carmen Ríos Rodríguez.
Writing – Review and Editing: Francisco Eneldo López Monteagudo, Jesus Gerardo Ávila Sánchez, Francisco Javier Martinez Ruiz, Leticia del Carmen Ríos Rodríguez.
Resources: Francisco Eneldo López Monteagudo, Jesus Gerardo Ávila Sánchez, Francisco Javier Martinez Ruiz, Leticia del Carmen Ríos Rodríguez.
Supervision: Francisco Eneldo López Monteagudo, Jesus Gerardo Ávila Sánchez, Francisco Javier Martinez Ruiz, Leticia del Carmen Ríos Rodríguez.
Approval of the final text: Francisco Eneldo López Monteagudo, Jesus Gerardo Ávila Sánchez, Francisco Javier Martinez Ruiz, Leticia del Carmen Ríos Rodríguez.

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RESEARCH ARTICLE OPEN ACCESS

CHARACTERIZATION OF A LOW POWER WIND TURBINE PROTOTYPE FOR INTERCONNECTION TO THE GRID

Juan Carlos Guerrero Luján[1], Francisco Eneldo López Monteagudo*[2], Jorge De La Torre y Ramos[3], Leticia del Carmen Ríos Rodríguez[4]

[1, 2, 3, 4] Autonomous University of Zacatecas, Av. López Velarde No. 801 CP 98060 Zacatecas, México.

[1] http://orcid.org/0009-0005-7717-7466, [2] http://orcid.org/0000-0001-6082-1546, [3] http://orcid.org/0000-0002-6601-2050, [4] http://orcid.org/0000-0002-1005-020X

Email: jc.guerrero.lujan@gmail.com, *eneldolm@yahoo.com, jorgetorre@uaz.edu.mx, leticia.rios@uaz.edu.mx

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ABSTRACT

In this article, a prototype of a low power wind turbine interconnected to the NETWORK and the controlled electronic converter for the rectification of the generated voltage was designed, which is used for the conditioning of the electrical power generated by low power wind systems for the Connection to the electric grid. Using different electronic components and free hardware development boards, the construction of a controlled three-phase rectifier prototype was carried out, divided into 3 modules, the first one in charge of obtaining a reference signal and synchronization of the voltage to be rectified, the second is the control circuit, which performs the time calculations for the activation of the third module, in charge of rectifying the triphasic voltage using thyristors (SCR), in which the moment of activation of the semiconductors can be controlled. Finally, tests of the prototype connected to a wind turbine built by teachers and students of the Technological University of Campeche were carried out, verifying its correct operation in the rectification of the voltage delivered by this generator.

I. INTRODUCTION

Energy obtained from wind provides an important part of the world's electrical energy to satisfy energy requirements, so it is necessary to have technologies that can take advantage of wind energy [1]. The objective of this research is to design, build and characterize a prototype of a low-power wind turbine for interconnection to the grid.

For the extraction of the kinetic energy of the wind and its conversion to useful energy for different activities and needs, in this development work a low-power wind generator for the purpose of converting the kinetic energy of the wind into electrical energy.

There are different topologies to convert the gross energy of the turbine into useful electrical energy. The most common way to use the energy provided by a wind turbine is the use of a rectifier followed by an inverter to connect it to an independent system. In this work, a converter and its control system for synchronization to the grid were developed [2].

To improve the performance of power converters, matrix converters described in [3] can be used. The energy extracted from the wind contributes to meeting energy demand, which is why the use of electronic converters is necessary, [4].

An inverter is needed to inject the energy obtained from the wind turbine into the electrical grid. Which regulates the speed of the turbine to obtain greater energy availability. The big disadvantage is the need for an active compensator for the reactive power demand, [5].

There are various control strategies for wind turbines which allow them to be classified, considering the advantages and disadvantages of the control algorithms to define future research trends. In [6] a critical review of the state of the art of wind turbine control technologies is carried out. wind turbines.

Wind turbines using doubly fed induction generators have many advantages, such as adjustable speed, constant frequency operating mode, self-governing powers for voltage and frequency control, active and reactive power controls, and maximum power point tracking. Artificial Intelligence can be used to control the turbine. There are various machine learning methodologies that allow the development of diagnostic tools to improve accuracy and stability, according to [7].

For the practical implementation of wind turbine control systems, different advanced control tools can be used. For large wind turbines it is increasingly complex, currently high-level optimization techniques are imposed to satisfy the design requirements. Within these techniques, multi-object optimal control, in particular, is a widely used methodology to achieve a control system that reconciles multiple design objectives that may normally be incompatible according to [8].

II. METHODOLOGY

In this article, the electrical characterization of two wind turbines was carried out, the first was a commercial model "iSTA Breeze i-500" and the second is an experimental design developed by the Technological University of Campeche (Mexico). Both wind generators produce up to 500 W of electrical energy. The characterization of the wind turbines was carried out using a characterization setup specifically designed for this purpose, allowing the main characteristics of both generators to be evaluated under controlled conditions.

The test bench for the characterization of the generators consists of a 5 H.P three-phase motor, driven by a frequency converter. Figure 1 shows part of the test bench, using the frequency converter, the rotation speed of the generator under test is regulated, obtaining different voltages, currents and powers for different speed conditions.

Figure 1: Testing bench.
Source: Authors, (2024).

The results of the tests carried out with the commercial generator and the prototype are shown in tables 1, 2 and 3.

Table 1: Results obtained in open circuit.

Open circuit test						
RPM	Commercial wind turbine			Prototype		
	Phase voltage A-B	Phase voltage A-C	Phase voltage B-C	Phase voltage A-B	Phase voltage A-C	Phase voltage B-C
511	11.84	11.61	11.84	37.46	36.97	37.81
466	10.80	10.73	10.76	34.08	33.77	34.23
423	9.87	9.68	9.77	30.85	30.73	31.42
382	8.83	8.72	8.81	27.99	27.73	28.12
340	7.58	7.74	7.83	24.80	24.68	25.03
297	6.86	6.77	6.84	21.68	21.62	21.92
255	5.88	5.80	5.86	18.59	18.52	18.77
212	4.89	4.83	4.83	15.54	15.43	15.59
169	3.95	3.88	3.89	12.33	12.36	12.51

Source: Authors, (2024).

As seen, at a given speed without load, the prototype can generate a higher voltage, for example 511 RPM, the prototype generates 37.81 V, almost 4 times the 11.84 V produced by the iSTA Breeze turbine at the same speed.

Table 2: Results obtained with three-phase load.

Commercial wind turbine									
RPM	Phase voltage A-B	Phase voltage A-C	Phase voltage B-C	Phase current A	Phase current B	Phase current C	Phase power A	Phase power B	Phase power C
511	9.60	9.51	11.11	1.30	1.30	1.40	12.48	12.36	15.55
464	8.63	8.55	10.08	1.20	1.20	1.30	10.36	10.26	13.10
424	7.73	7.66	9.02	1.10	1.20	1.20	8.50	9.19	10.82
382	6.84	6.74	7.98	1.10	1.10	1.10	7.52	7.41	8.78
341	5.95	5.87	6.98	1.00	1.00	1.00	5.95	5.87	6.98
299	5.06	5.01	5.92	0.90	0.90	0.90	4.55	4.51	5.33
254	4.22	4.18	4.88	0.70	0.70	0.80	2.95	2.93	3.90
214	3.43	3.36	4.02	0.50	0.50	0.60	1.72	1.28	2.41
169	2.63	2.56	3.00	0.30	0.30	0.30	0.79	0.77	0.90

Source: Authors, (2024).

Table 3: Results obtained with three-phase load.

Prototype									
RPM	**Phase voltage A-B**	**Phase voltage A-C**	**Phase voltage B-C**	**Phase current A**	**Phase current B**	**Phase current C**	**Phase power A**	**Phase power B**	**Phase power C**
511	33.95	33.81	34.52	2.20	2.40	2.30	74.69	81.14	79.40
464	30.92	30.77	31.14	2.20	2.30	2.20	68.02	70.77	68.51
424	28.13	28.11	28.32	2.00	2.10	2.00	56.26	59.03	56.64
382	24.99	24.99	25.28	1.80	2.00	1.80	44.98	49.98	45.50
341	22.04	22.04	22.31	1.70	1.80	1.70	37.47	39.67	37.93
299	19.03	19.04	19.28	1.50	1.60	1.50	28.55	30.46	28.92
254	16.00	16.13	16.43	1.30	1.40	1.30	20.80	22.58	21.36
214	13.22	13.17	13.22	1.10	1.20	1.10	14.54	15.80	14.54
169	10.29	10.27	10.37	0.80	0.90	0.80	8.23	9.24	8.30

Source: Authors, (2024).

As observed in the second test, with resistive load, approaching real operating conditions, the prototype provided 74.69 W, 81.14 W and 79.40 W per phase at 511 RPM, using equation 1, we obtain that the Total turbine power provided by the generator is 235.23 W, while the commercial model delivered 12.48 W, 12.36 W and 15.55 W per phase, giving a total of 40.39 W, which is 5 times less than the power delivered by the prototype.

$$P(total) = (\sum_{i=1}^{n} Vi * Ii)(W) \quad (1)$$

Figure 2 shows the average output voltages per phase of both wind turbines.

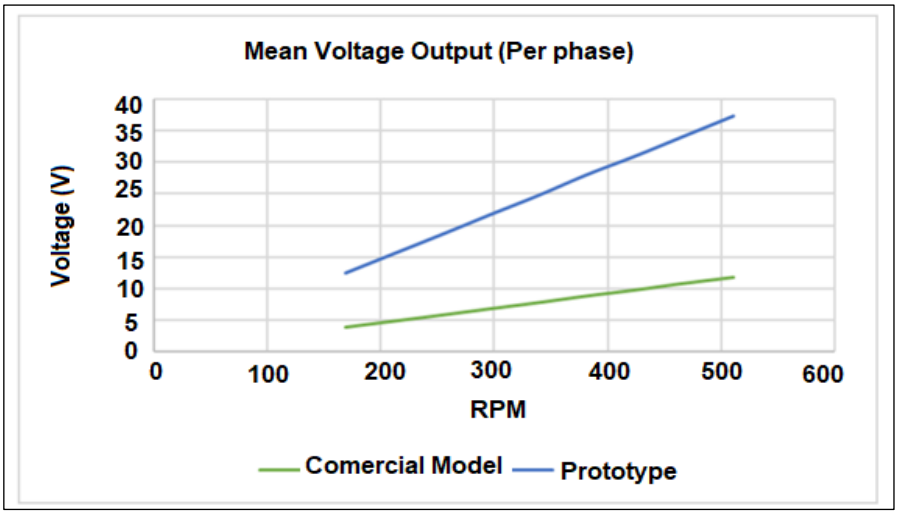

Figure 2: Output voltages.
Source: Authors, (2024).

In figure 3 you can see the difference in power delivered with three-phase load by the wind turbines under the same conditions.

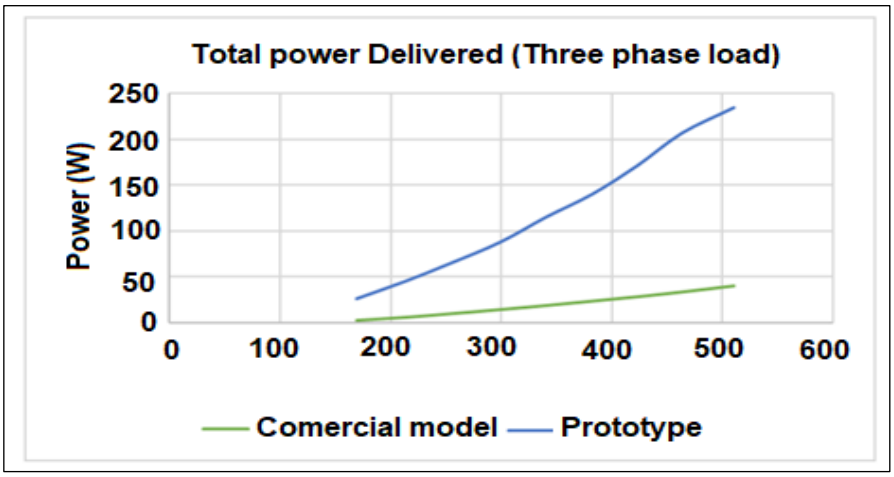

Figure 3: Output voltages.
Source: Authors, (2024).

III. TESTING OF THE DEVELOPED PROTOTYPE

Figure 4 shows the basic configuration of the three-phase full-bridge rectifier, used in the prototype. The input of the phases coming from the wind turbine can be seen, as well as the input of the firing pulses through the thyristor gates (SCR), the SCRs at the top have the same reference (ground) for their activation, while the SCRs at the bottom, each one has its own reference. The pulses applied to the SCRs allow current to flow through them, in the necessary time, thus achieving the desired rectification.

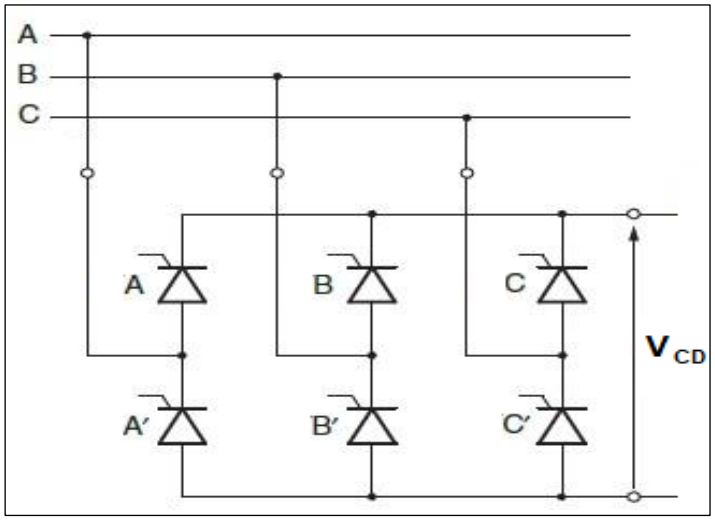

Figure 4: Full Bridge Rectifier with SCRs.
Source: Authors, (2024).

To characterize the generator prototype, the test bench was configured to obtain different output voltages. Figure 5 shows the generator outputs at different speeds.

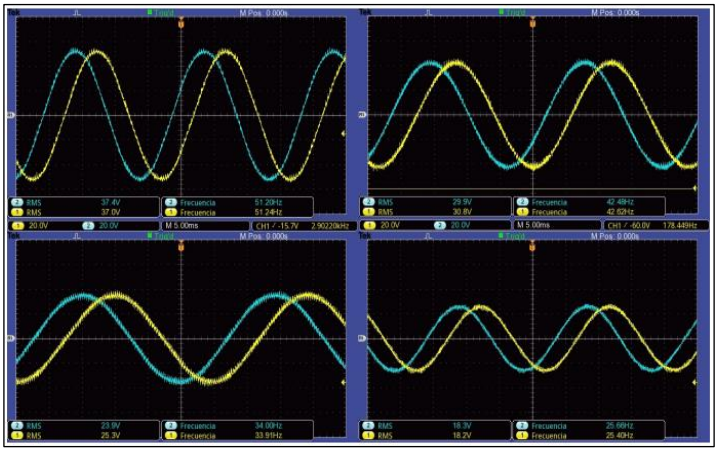

Figure 5: Wind Turbine Voltage Outputs.
Source: Authors, (2024).

In the prototype, different firing angles were used, at 0° (without delay in activating the SCR trigger), 18° (10% duration of the half cycle in delay), 36° (20% duration of the half cycle in delay), 54° (30% duration of the half cycle in delay), 72° (40% duration of the half cycle in delay), for the different levels of generated voltages. Table 4 shows the voltage outputs of the prototype with different firing angles at different speeds.

Table 4: Results obtained in open circuit.

RPM	Maximum Voltage	RMS voltage	Output voltages at different shooting angles				
			0º	18º	36º	54º	72º
511	53	37	49	46.7	46.4	45.5	43.5
423	44	30	40.2	40.3	38.1	38.5	38
340	35	25	31.2	29.9	30	27.6	29.2
255	26	18	22.1	22.4	21.8	20.8	20.8

Source: Authors, (2024).

In Figure 6, a 90 Hz sinusoidal signal is observed, which is taken as a reference to calculate the length of the trigger signals that are applied to the SCRs. In the same figure, the signals that activate the SCRs in one cycle are observed. of work.

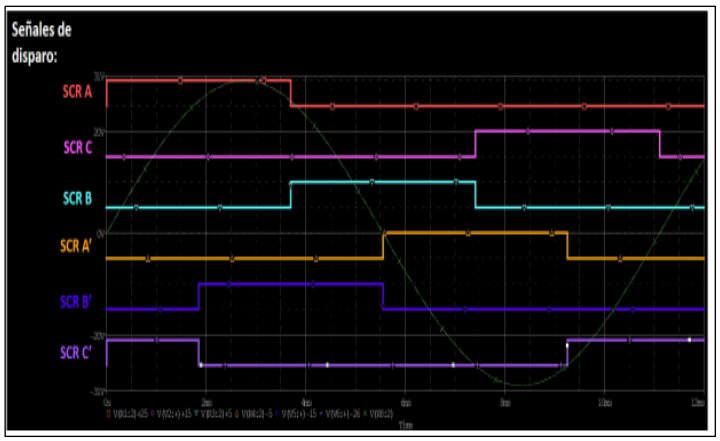

Figure 6. SCR Firing Order.
Source: Authors, (2024).

The trigger signals are generated by the control circuit, depending on the frequency that the wind turbine is delivering. The Arduino platform was used for the generation and synchronization of the trigger signals, due to its variety of options, compatibility, use of hardware and free software, flexibility, ease of use and large community of developers and users.

IV. CONCLUSIONS

The wind turbine prototype showed better performance compared to the commercial model, recognizing that there are large voltage variations in the prototype when the RPM decreases. This can be improved by reducing the air gap between the rotor and stator.

The prototype presents acceptable performance; its use with a controlled rectifier and a multilevel inverter for grid-connected operation is recommended. It is recommended to improve wind turbines and their conversion system in order to obtain the majority of wind energy and minimize power losses in the conversion to contribute to reducing dependence on polluting energy generation.

V. AUTHOR'S CONTRIBUTION

Conceptualization: Francisco Eneldo López Monteagudo, Juan Carlos Guerrero Lujan, Jorge de la Torre y Ra, Leticia del Carmen Ríos Rodríguez.
Methodology: Francisco Eneldo López Monteagudo, Juan Carlos Guerrero Lujan, Jorge de la Torre y Ra, Leticia del Carmen Ríos Rodríguez.
Discussion of results: Francisco Eneldo López Monteagudo, Juan Carlos Guerrero Lujan, Jorge de la Torre y Ra, Leticia del Carmen Ríos Rodríguez.
Writing – Original Draft: Francisco Eneldo López Monteagudo, Juan Carlos Guerrero Lujan, Jorge de la Torre y Ra, Leticia del Carmen Ríos Rodríguez.
Writing – Review and Editing: Francisco Eneldo López Monteagudo, Juan Carlos Guerrero Lujan, Jorge de la Torre y Ra, Leticia del Carmen Ríos Rodríguez.
Resources: Francisco Eneldo López Monteagudo, Juan Carlos Guerrero Lujan, Jorge de la Torre y Ra, Leticia del Carmen Ríos Rodríguez.
Supervision: Francisco Eneldo López Monteagudo, Juan Carlos Guerrero Lujan, Jorge de la Torre y Ra, Leticia del Carmen Ríos Rodríguez.
Approval of the final text: Francisco Eneldo López Monteagudo, Juan Carlos Guerrero Lujan, Jorge de la Torre y Ra, Leticia del Carmen Ríos Rodríguez.

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RESEARCH ARTICLE OPEN ACCESS

ESTIMATION OF REFRACTIVITY GRADIENTS AND EFFECTIVE EARTH RADIUS FACTOR (K-FACTOR) IN THE LOWEST 100 M OF THE ATMOSPHERE OVER OGBOMOSO, SOUTHWESTERN NIGERIA

Kamaldeen O Suleman[1]*, Saheed B Suleiman[2], Lukman A Sunmonu[3] and Akeem L Sheu[4]

[1] Department of Physics, School of Basic Sciences, Nigeria Maritime University, Okerenkoko, P.M.B. 1005, Warri, Delta State, Nigeria.
[2] Department of Software Engineering, Baba Ahmed University, Kano, Kano State, Nigeria.
[3] Department of Pure and Applied Physics, Ladoke Akintola University of Technology, P.M.B. 4000, Ogbomoso, Oyo state. Nigeria.
[4] Department of Physics, Emmanuel Alayande College of Education, Oyo, Oyo State, Nigeria.

[1] http://orcid.org/0000-0002-9103-1974, [2] http://orcid.org/0009-0000-1556-1837, [3] http://orcid.org/0000-0002-4305-8363, [4] http://orcid.org/0000-0003-4877-880X

Email: *kamaldeen.suleman@nmu.edu.ng, simplysaheed@gmail.com, lasunmonu@lautech.edu.ng

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ABSTRACT

Upon deviation from standard condition, anomalous propagations are usually experienced in within the atmosphere. As a result, it is very pertinent to considered the value of the tropospheric refractive index while planning, designing and implementing microwave systems. In this study, measurements of meteorological parameters (temperature, relative humidity, and atmospheric pressure) were conducted for a period of 12 months (Jan - Dec, 2021) in Ogbomoso (8.17ºN, 4.24ºE, 372 m above sea level) using a collection of wireless Davis Vantage Pro2 6162 automatic weather stations. The hourly time series of these measured data were extracted and converted to monthly averages and used to compute refractivity, gradient of refractivity, and the k-factor. From the Analyses, results revealed a generally high values of refractivity during the rainy months with a peak value of 359 recorded in May. The values were observed to decrease with increasing height. For the period of this observation, the mean refractivity gradient was found to be 50 N-units/km while the average value of K-factor was 1.49. As a result, it was concluded from these findings that the propagation condition in Ogbomoso is super-refraction.

I. INTRODUCTION

When planning and designing microwave systems, one of the most important parameters to be considered is the value of the tropospheric refractive index. The radio refractive index is often defined as the ratio of the velocity of propagation of radio wave in a free space to the velocity of propagation of radio wave in a specified medium [1–5].

Upon deviation from standard condition, anomalous propagations are usually experienced in within the atmosphere. Changes in meteorological conditions which include temperature inversion and high humidity are believed to be responsible for these aberrations. These meteorological parameters usually exhibit high temporal and spatial variability, with small alterations resulting in significant influence on radio signals [4]. Near the Earth's surface, under standard atmospheric conditions, the radio refractive index is equal to approximately 1.0003 [1], but it is usually not constant under the above mentioned conditions. Changes in the value of the radio refractive index can lead to alterations in the path of the wave.

The term refractivity is mostly used owing to the fact that the value of the refractive index is usually close to unity and exhibits very small temporal and spatial variability [1], [2], [6].

From available literature, several work have been carried out to study the refractivity profiles across different locations in Nigeria [3-5, 7–21]. However, there is dearth of information on the radio refractivity profile in Ogbomoso, as most of the previous

works within the southwestern part of Nigeria are restricted to Lagos and Akure. Moreover, climate impacts have identified changes in the meteorological variables with increasing adverse effects on radio link outages over the last few decades. Insight into this trend suggests that the Quality of Service (QoS) provided by the communication links will be even more severely affected over next decades. Hence, there is a need to carry out further studies to understand the radio refractivity profiles with a view to improving quality of service in the area.

As a result, in this study, real time measurements of temperature, relative humidity, and atmospheric pressure were conducted for a period of two years in Ogbomoso (8.17 ºN, 4.24 ºE, 358 m above sea level). The measured data were extracted and used to compute radio refractivity, N, the refractivity gradient, dN/dh and the effective Earth radius factor, K-factor.

II. THEORETICAL BACKGROUND

The troposphere is a region of the atmosphere extending from the surface of the earth up to an altitude of about 9 km and 17 km at the poles and equator, respectively [22], and it is the lowest part of the earth's atmosphere. The upper boundary where the temperature begins to experience an increase with altitude is the tropopause. However, within the troposphere, the temperature has been found to drop with altitude at a rate, which has been reported to be approximately 7 ℃ per kilometre [22, 23]. Owing to confinement of the earth's weather system to the troposphere, variations in meteorological parameters such as humidity, temperature, and pressure usually results in variation in the refractive index of air in this layer from one point to another.

Generally, it has been established that the tropospheric refractive index, n, decreases with altitude [23,24]. In most discussions relating to this, horizontal homogeneity is usually assumed while neglecting variations in the horizontal path. As mentioned earlier, no noticeable deviation is usually observed since the change in the refractive index is negligibly small. One other important characteristics of the atmosphere is the gradient of refractivity, G, which is responsible for the change in propagation direction of the electromagnetic wave [25]. It is an important parameter when classifying refractive conditions of the troposphere

When taking into account, the correlation between refractivity and the primary weather parameters, it is customary to evaluate refractivity using Equation 1 [3, 22, 24].

$$N = 77.6\frac{P}{T} + 3.73\times10^{5}\frac{\varepsilon}{T^{2}} \tag{1}$$

Here, P is the pressure measured in hPa, T is temperature in Kelvin and ε is water vapour pressure in hPa. Equation 2 is only valid for radio waves with frequencies not exceeding 100 GHz and have an allowed error limit of less than 0.5 % [6, 26].

Prior to implementing equation 1, it's important to first evaluate equations 2 and 3 as given.

$$\varepsilon = H\times\frac{\varepsilon_s}{100} \tag{2}$$

$$\varepsilon_s = 6.1121\exp\left(\frac{17.502t}{t+240.97}\right) \tag{3}$$

In this case, t is the temperature in ℃.

The k-factor which we will sometimes referred to as the effective earth radius factor is a scaling factor which helps in the quantification of the curvature of an emitted ray path. It is defined as the ratio of the radius, R, of a ray beam curvature to the effective radius of the earth, R_e.

However, radiolink engineer take more direct interest in the refractivity gradient G. To express k -factor as a function of this gradient, it is convenient to assume that the refractive index, n, of air varies linearly with height h within the first few tenths of a kilometre above the earth's surface and invariant in the horizontal direction. It is this argument that led to the mathematical expressions.

$$\frac{R}{R_e} = k \approx \left(1+\frac{R_e\Delta n}{\Delta h}\right)^{-1} \tag{4}$$

$$\frac{\Delta n}{\Delta h} = \frac{\Delta N}{\Delta h}\times10^{-6} \qquad N-units/km \tag{5}$$

where R_e is approximately 6370 km and is the height above the earth's surface.

The gradient of refractivity and effective earth radius factor were estimated using Equations 6 and 7, respectively.

$$\frac{\Delta N}{\Delta h} = -\frac{N_s}{H}\exp\left(-\frac{h}{H}\right) \tag{6}$$

$$K \approx \left(1+\left(\frac{\frac{\Delta N}{\Delta h}}{157}\right)\right)^{-1} \tag{7}$$

Radio refractivity may be classified as: sub-refraction, standard refraction, super-refraction or trapping, depending on the existing tropospheric conditions. When the gradient of refractivity is less than -40 N-units per kilometre, the troposphere is said to be super-refractive and radio signals travelling within it will undergo a downward refraction at a rate less than the curvature of the earth. However, when the refractivity gradient is less than -157 N-units per kilometre will produce a ray that bend downwards the earth's surface with a curvature greater than the curvature of the earth, a condition commonly referred to as trapping. Radio energy can become trapped between a boundary or layer in the troposphere and the surface of the earth or sea (surface duct). Far beyond the line-of-sight, very high signal strengths can be obtained at very long range during ducting [3, 23, 24, 27]. Lastly, for a refractivity gradient that is greater than -40 N-units per kilometre, the troposphere become sub-refractive and radio rays will refract upwards, away from the surface of the earth [23].

III. MATERIALS AND METHODS

The site of the study is the high-rise laboratory complex of the Department of Pure and Applied Physics, Ladoke Akintola University of Technology Ogbomoso, Oyo State Nigeria (8.17 ºN, 4.24 ºE) as indicated on the map in Figure 3. The instrumentation system consists of a Davis 6152 wireless vantage pro2 automatic

weather station with an in-built power system provided by a constrained solar-powered unit as shown in Figure 4. The Integrated Sensor Suite (ISS) comprises of several sensors that measures basic weather parameters including rainfall, temperature, relative humidity, UV index among others. The ISS also has a sensor interface module (SIM) which contains electronic circuits that measures and stores values of weather variables for transmission via a wireless console via radio.

The measurement employed the fixed measuring approach, where the ISSs are stationed on the ground and at heights of 50 m and 100 m respectively, for continuous measurement of the atmospheric pressure, air temperature and relative humidity. The time of measurements is from 00 hours local time for 24 hours with an integration time of 60 minutes. Using a wireless terminal, the observation data was transmitted to a data logger attached to the console which was kept on the ground. The logged data are saved temporarily on a laptop for analysis. The allowed error margins for temperature, pressure and relative humidity was set at ± 0.1, ±0.5 hpa and ±2 % respectively.

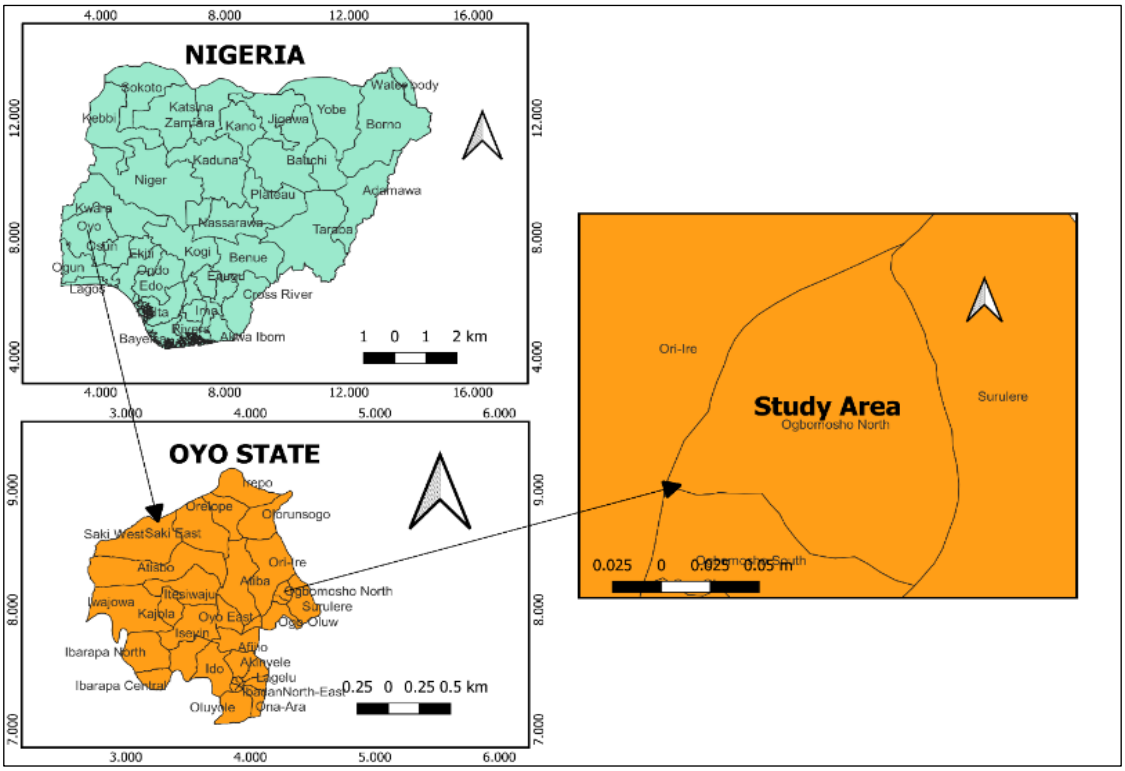

Figure 3: Map of the Study area.
Source: Authors, (2024).

Figure 4: One of the Automatic Weather stations on site in LAUTECH.
Source: Authors, (2024).

The hourly time series of the measured data were used to estimate the values of refractivity, gradient of refractivity and k-factor, respectively. Data analyses and graphing were done using Microsoft excel and OriginPro software.

IV. RESULTS AND DISCUSSIONS

IV.1 MEAN MONTHLY RADIO REFRACTIVITY

Variations in the refractivity over Ogbomoso is presented in Figure 5. During the rainy season which usually occur between March-October, the values of refractivity were observed to be very high, reaching a peak value of 375 N-units in May. This trend, which is in agreement with the result of [3], could be attributed to the high relative humidity (more than 80 %) usually observed in as Ogbomoso is usually subjected to large moisture-filled tropical maritime air arising from continual movement of inter-tropical discontinuities. Between July and August, a slight decrease, attributed to a brief break in rainfall, was observed.

During the dry season however, between November and February, there was a noticeable decline in the refractivity values, having recorded values ranging between 325-354 N-units. We attributed this trend to the presence of dry and dust-laden north-west winds which become dominant in the month of December, that usually setthe path for the dry harmattan season. A slight

decrease in refractivity observed in the July–August window is attributed to a brief break in rainfall in the month of August which usually last for about 2-3 weeks.

Generally, the values of refractivity at 2 m (herein referred to as ground level) and other levels differs significantly throughout the entire period of observation, with the refractivity decreasing with height. This is attributed to low ground heat flux and high prevalence of temperature and humidity inversions, leading to low surface temperature and consequently high values of refractivity. The average value of refractivity in Ogbomoso was recorded as 359 N-units.

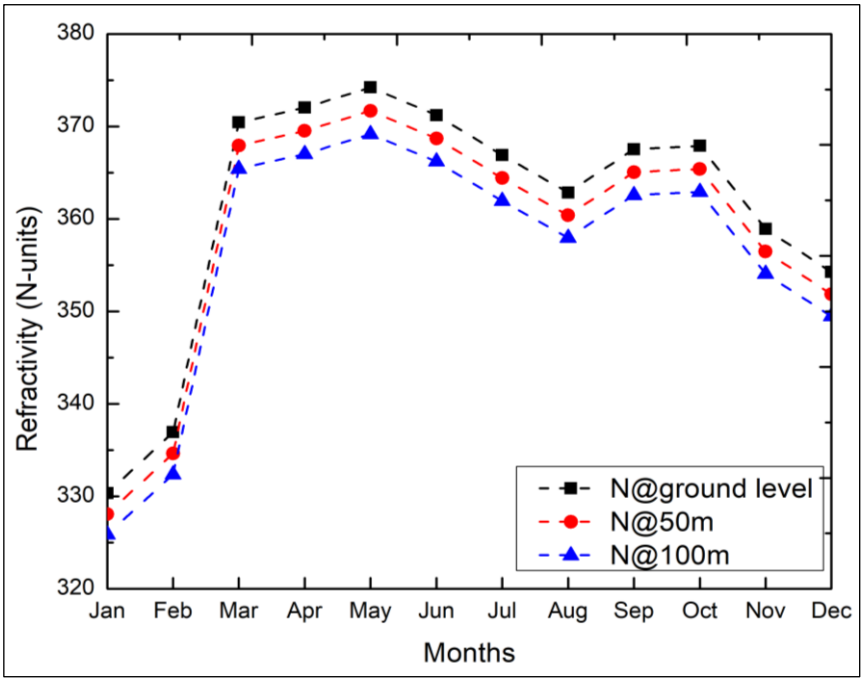

Figure 5: Variations of radio refractivity in Ogbomoso for the year 2021.
Source: Authors, (2024).

IV.2 MEAN MONTHLY REFRACTIVITY GRADIENT

Variations in the vertical refractivity gradient over Ogbomoso is presented in Figure 6. As observed the graph showed irregular pattern that is best described as oscillatory. The refractivity gradient reaches its peak value (-45 N-units per km) in the month of January with the least value recorded in the month of May. The period of peak refractivity gradients coincides with period of intense harmattan in Ogbomoso, which is usually characterised by very cool nights and morning times and very dry day time. The average value of refractivity gradient was found to be -50 N-units/km. From these observation, it was inferred that propagation conditions in Ogbomoso is mostly super-refractive and radio wave transmitted here will have increased range.

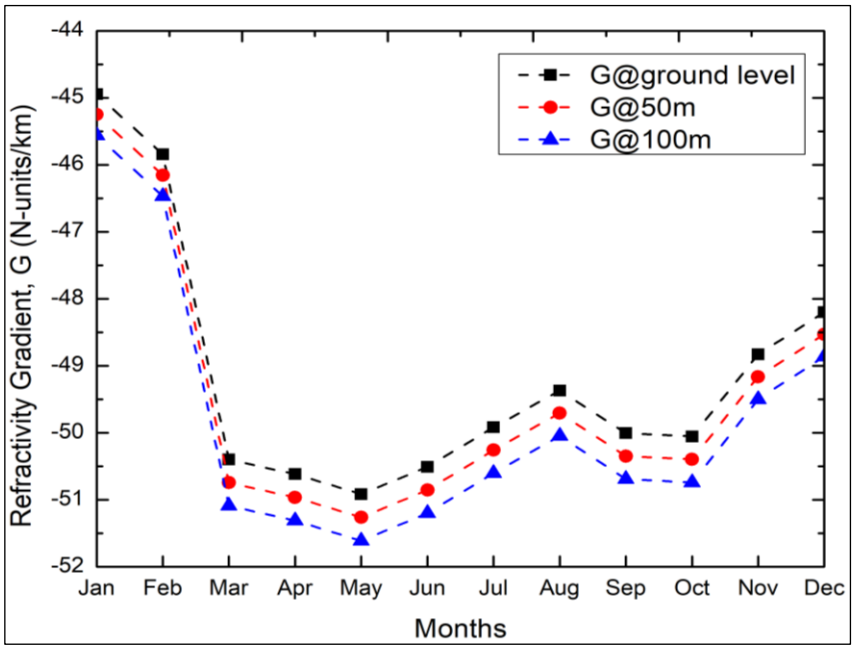

Figure 6: Monthly variations of refractivity gradient in Ogbomoso for the year 2021.
Source: Authors, (2024).

IV.3 MEAN MONTHLY EFFECTIVE EARTH-RADIUS FACTOR

The monthly mean variations of the effective earth radius factor (K-factor) is displayed in Figure 7. Here, it was observed that the K-factor is low in the dry period. For the dry and wet seasons, the values range from 1.40 to 1.45 and 1.45 to 1.49, respectively. These results agree favourably with that of Kolawole (1981), who reported that the effective earth's radius factor, K, is usually lowest over Nigeria in the month January with values in the range 1.12 – 1.38 and highest values varying from about 1.30 to 1.50. In the present study, the average value of K-factor is about 1.49. While the work of Kolawole (1981) suggested that the value of the K-factor usually reaches its peak in the month of August, the present study however found this to not be so, as the highest value of K-factor was recorded in the month of May. This variation could be attributed to the influence of climate change over the years.

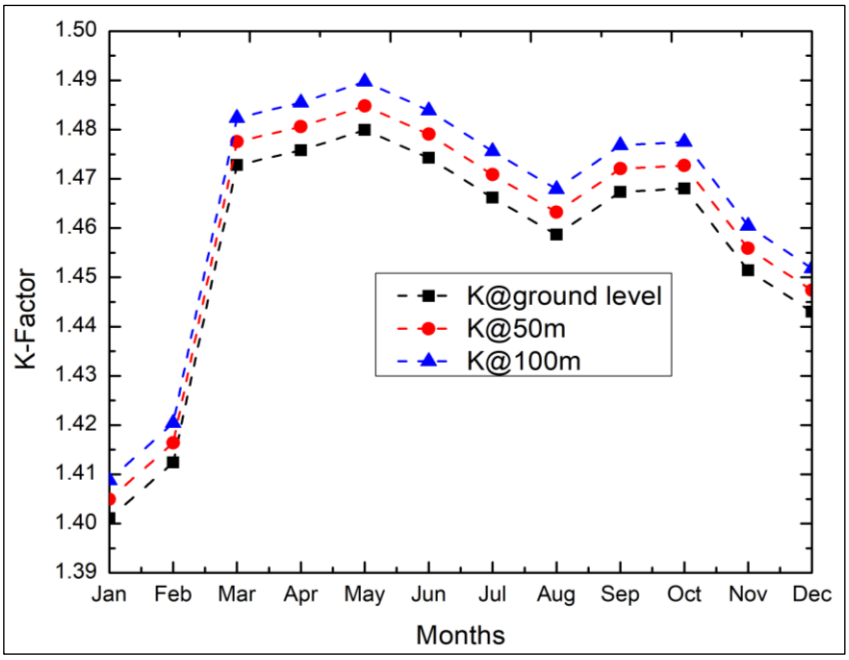

Figure 7: Monthly variations of effective earth radius factor in Ogbomoso for the year 2021.
Source: Authors, (2024).

V. CONCLUSIONS

In this work, the vertical refractivity profile, refractivity gradient, and effective earth radius factor in the first 100 m of the troposphere over Ogbomoso was investigated based on experimental measurements with a view to characterizing the propagation conditions of the atmosphere. Analysis revealed that the surface refractivity is generally high during the rainy reason for all levels considered, with a marked decrease in the dry months of December and January, when the dry harmattan is usually intense. The average value of surface refractivity recorded in this study is 359 N-units with a corresponding average value of refractivity gradient and k-factor of -50 N-units/km and 1.49, respectively. Based on these results, the study therefore concluded that, the atmospheric propagation condition in Ogbomoso is mostly super-refractive.

VI. AUTHOR'S CONTRIBUTION

Conceptualization: Suleman Kamaldeen and Sheu Akeem Lawal.
Methodology: Suleman Kamaldeen and Sheu Akeem Lawal.
Investigation: Suleman Kamaldeen and Suleiman Saheed.
Discussion of results: Suleman Kamaldeen and Sheu Akeem Lawal.
Writing – Original Draft: Suleman Kamaldeen. and Suleiman Saheed.
Writing – Review and Editing: Suleman Kamaldeen and Sunmonu Lukman.
Resources: Suleiman Saheed.
Supervision: Sunmonu Lukman.
Approval of the final text: All Authors.

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RESEARCH ARTICLE OPEN ACCESS

OPTIMAL TUNING OF PID CONTROLLER PARAMETERS FOR AGC OF A WIND INTEGRATED INTERCONNECTED POWER SYSTEM

Gottam Venkata Supriya*[1], M Ramasekhara Reddy[2] and P Bharat Kumar[3]

[1] PG Student, M. Tech (Control Systems), Department of Electrical and Electronics Engineering, JNTUA College of Engineering, Anathapuramu, India.

[2] Assistant Professor and Head of the Department in Electrical and Electronics Engineering, JNTUA College of Engineering, Anathapuramu, India.

[3] Assistant Professor (Adhoc) in Electrical and Electronics Engineering, JNTUA College of Engineering, Anathapuramu, India.

[1] http://orcid.org/0009-0002-8533-5653, [2] http://orcid.org/0000-0002-3754-3995, [3] http://orcid.org/0000-0002-7788-0398

Email: *gvsupriyareddy@gmail.com, ramasekharreddy.eee@jntua.ac.in, pbk.eee@jntua.ac.in.

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ABSTRACT

The interconnected power systems response control has become more challenging with the integration of wind energy due to the variable range of wind speed and power output. In addition to load perturbations, fluctuations in wind power can also impact system frequency. Therefore, enhancing current control strategies is essential to maintain the stability of the frequency in these complex power system scenarios. The Controller is tuned in three methods. The new tuning methods are introduced to the conventional proportional-integral and derivative controller such that the system gives best performance. These tuning methods are Genetic Algorithm (GA) and Harmony Search Algorithm (HSA) used to study the system performance in comparison between them on Time Domain Analysis. The system is also tested for its robustness in three cases as the nominal loads for both the areas and with the load disturbance and the controller by its gain variations. The system's results are acquired through the utilization of the MATLAB/Simulink software.

I. INTRODUCTION

The network developed to supply, transfer and use electric power by the electrical component is a Power System. To increase the reliability of power system, increase the efficiency of plants and to reduce the operating cost (cost of power generation) an Interconnected Power System is introduced. This interconnected power system is the direct connection between two or more power systems. Generally, the integration of power systems is done between the Renewable Resources to a power network such as Power Grid and Renewable Resources like Photovoltaic (PV), Wind Turbines, Fuel Cells (FC) and Energy Storage Systems etc.., The expansion of renewable energy sources is being driven by various factors, including a shortfall in generation capacity, rising fuel costs, environmental problems, and the threat of global warming. In this project, a two-area interconnected power system is employed, each area containing multiple generators closely linked to form a coherent group where the overall system response can be observed in different cases i.e., the problems which must be phased during its operations.

The integration of renewable energy causes the disturbance to the system like synchronizing problem, frequency control, voltage control and their stability. The main objective of this project is to nullify the deviations from the load frequency regulations and tie-line power from their initial values. The deviations can be observed in the Area Control Error (ACE), and this is reduced by an ancillary service like Automatic Generation Control (AGC). The main objective of this AGC is to select the appropriate speed regulation which can reduce the frequency fluctuations. To tune control parameters an optimization algorithm is very much useful like SOS Algorithm, CRSO Algorithm, GA, HSA, etc.., which gives better performance and stable response. Since, the considered power system may contain nonlinearities like governor dead band, boiler dynamics, appropriate controllers are to be selected where cascading of the controller is possible.

This study focuses on analysing the system, where area-1 incorporates one thermal plant integrated with wind power, while area-2 comprises a single Thermal Plant.PID control strategy will be proposed for designing of controller in both the areas. To tune PID controller parameters, conventional and optimization methods will be used. The comparative analysis will be carried out by using different tuning methods. The entire project will be conducted within the MATLAB/Simulink environment.

II. THEORETICAL REFERENCE

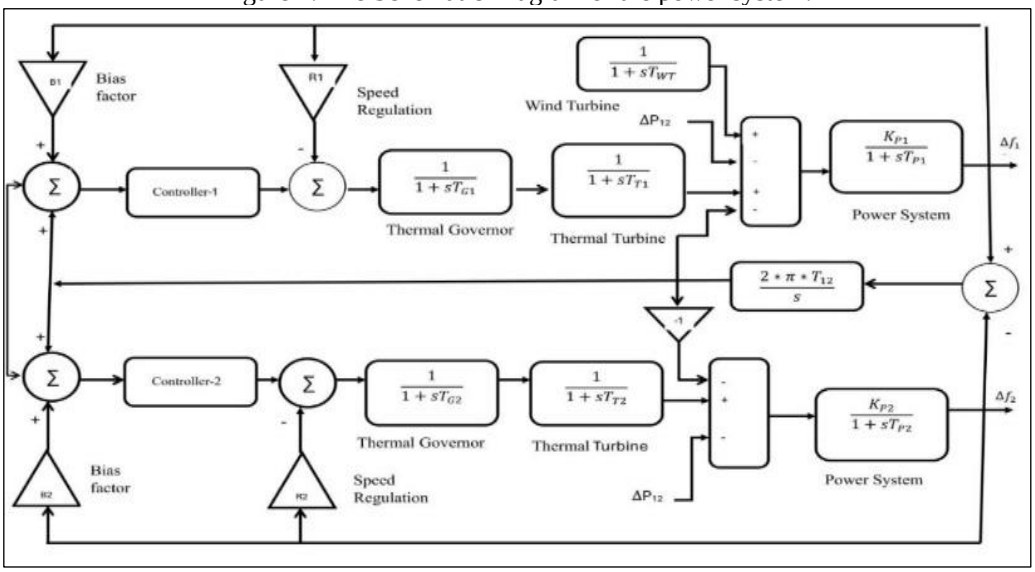
The basics of an interconnected power system and its problem is analysed by [1] and the solution of their problem is explained in [2] which is AGC strategy and how the interconnected systems burden the existed control system is explained in [3]. The different controllers used in AGC strategy and its mathematical models explaining the difference of performances between them in [3]. The robustness of the system different cases is observed in [4]. The response of the interconnected system by SOS algorithm based PID Controller in [5]. The performance of the system with two 2DOF-PID controllers in [6] and the optimization algorithm i.e., CRSOA and for the robustness of the system different cases are observed in [7] & [8]. The Controller tuned with fuzzy in [9]. The response of the system by Algorithm based PID Controller in [10].

III. SYSTEM STUDIED

An interconnected power system with two areas, incorporating wind and thermal units in each area, is analysed to evaluate the effectiveness of a new controller tuning. Figure 1 depicts the system block diagram, where area 1 accommodates a thermal plant integrated with sufficient wind generation, while area 2 relies solely on a thermal unit.

The investigation encompasses three cases to showcase enhanced stability within the system with the new controller under two wind cases. In Case 1, load perturbance are introduced in a specific area while wind unit remains constant. In Case 2, wind speed variations are limited, coinciding with regular load changes, with wind's overall impact on the system frequency constrained by demand fluctuations. In both cases, wind-induced changes insignificantly influence frequency oscillations compared to load perturbations. However, in Area I, wind speed/power alterations outweigh load disturbances, leading to pronounced frequency oscillations.

Figure 1: The Schematic Diagram of the power system.



Source: [1].

Hence, it is crucial to design effective controllers to alleviate frequency disturbances arising from fluctuations in the system. Load perturbations are generated using step functions, while wind unit is represented using modelling techniques. System response is analysed employing a PID controller with Harmony Search Algorithm (HSA) tuning, contrasting with conventional PID and PID controllers with Genetic Algorithm (GA) tuning methods. A MATLAB/Simulation is conducted on the power system.

IV. CONVENTIONAL PID DESIGN

A conventional type of the PID controller is introduced for AGC of the two-area Interconnected power system. For the tuning of the gain parameters a conventional method i.e., Ziegler-Nichols Method is one of the practices among all the other tuning methods. By using this method, the PID controller is designed by the following.

Table 1: The formulae to determine the controller parameters.

Control type	K_p	K_i	K_d
Conventional PID	$0.6K_u$	$1.2K_u/T_u$	$0.075K_u*T_u$

Source: [6].

Here, Kp represents the proportional gain, Ki denotes the integral gain, and Kd signifies the derivative gain.

Here, K_u is the ultimate Gain, defined as 1/M, where M is the ratio of the amplitude which is derived from the closed loop response of the two-area interconnected system without the controller. To find the K_u, Initially, set the integral (K_i) and derivative (K_d) gains of the controller to zero, only the proportional gain (K_p) is used. By increasing the K_p gradually until the input system starts to oscillate (these oscillations are known as steady-state oscillations) with a constant amplitude. This K_p gain is considered as the ultimate gain (K_u). To measure the period of oscillations (T_u), which is the time it takes for the output waveform to complete one full cycle during steady-state oscillations.

From these parameter gains, when applied to the system by the Controller gives the controlled response of system. The controller gains derived as follows,

K_p=1.9987 K_i=1.98578 K_d=1.9928

V. GENETIC ALGORITHM BASED PID CONTROLLER DESIGN

In many controllers designed to reduce frequency oscillations in power plants, two reference input signals are commonly used: ACE and Δf. Traditionally, a controller employs the error signal as a standard in a scenario involving a system, while it uses Δf in an isolated scenario. However, since both signals are available in each area, employing Δf as the reference signal for the component in the controller proves advantageous. This method removes extra noise at the boundaries in the LFC and streamlines real-time applications, ensuring uniformity of the control problem's dimension even with changes in the areas. To enhance the tuning of these controller parameters, the GA is to fine-tune the parameters of the interconnected system comprising two areas. This utilization of GA aims to improve the system's performance and stability by tuning the controller's gains.

Genetic Algorithm is an intelligent exploitation of a random search. This algorithm works for this optimization problem as firstly, by selecting the fitness function, is formulated based on the load parameters and the objective function (J), which relies on selection of control parameters. Given a system with two areas and three output variables Δf in area 1 (Δf1), Δf in area 2 (Δf2), and power transfer in the system (ΔP12), the objective function is as follows:

Objective function

$$J = \int_0^t ((\Delta f1)^2 + (\Delta f2)^2 + (\Delta P12)^2) \quad (1)$$

Secondly, Initialize a population of chromosomes representing potential solutions to the optimization problem. The initial population could be generated randomly as

Population_size=30
Chromosome_length=24
Delta_Length=12
Generation_max=20

Evaluate the fitness of each chromosome in the population based on response of the objective function and constraints. In this system, fitness could be assessed based on stability, generation costs, tie-line power flows by giving optimum as [0 0 0 0] ,flag=0 and the generation=1.

By these, chromosomes derived as the matrix forms giving different parameter relations giving the optimal solutions as,

BestS= [Kpga Kiga]
Kdga= Kpid

Where Bests gives the gains of the proportional and integrator parameters Kd is the gain of the derivative parameter. If not, chromosomes from the current population to serve as parents for the creation of the next generation. Higher-fitness chromosomes are likely to be preferred, but some level of diversity should be maintained to avoid premature. The chromosomes can also be observed by parameters like damping ratio and setting time.

Apply crossover (recombination) to pairs of selected parent chromosomes to create offspring chromosomes for the next generation. Crossover entails swapping genetic material between parent chromosomes, enabling exploration of novel regions within the search space.

Introduce random changes (mutation) to some offspring chromosomes to maintain genetic diversity and explore new ranges of the search area. Mutation helps prevention in the algorithm from staying in local ranges. Replace current population with the offspring population created through selection, crossover, and mutation. Check termination conditions to determine whether the optimization process should be stopped. Termination criteria may encompass reaching a maximum generation, attaining an acceptable solution, or reaching a predetermined level of convergence.

Finally, Analyse the final population of chromosomes to pick out the best solution for the optimization problem. Evaluate the performance of optimized system with respect to chosen J and constraints. The final output can be observed as,

BestS = 89.2695 0.6113 25.5601

After number of iterations, the PID Controller parameters derived from the Genetic Algorithm are.

K_p=0.0012 K_i=-0.6000 K_d=89.2695

The Figure 2 explain the algorithm in the form of a Flow Chart for better understanding of its mechanism,

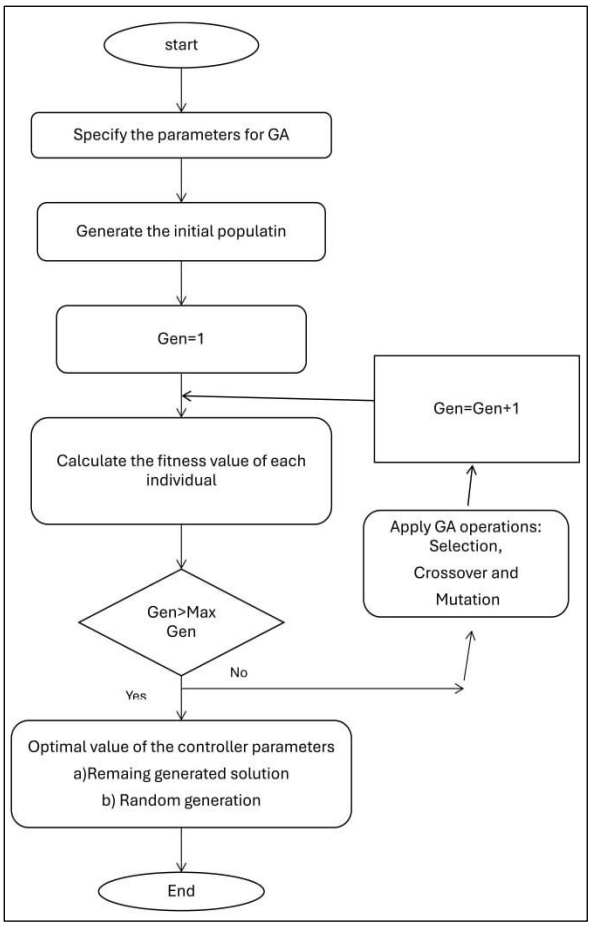


Figure 2: The flow chart of Genetic Algorithm.
Source: [11].

VI. HARMONY SEARCH ALGORITHM BASED PID CONTROLLER DESIGN

As Genetic Algorithm is a Random Optimization where the Harmony Search Algorithm is more of memory build i.e., the initial solution is taken from the genetic algorithm solutions and within that range this HSA derives the better optimal solution such that the two-area interconnected system in its AGC and Frequency changes (Optimization problems)

The HSA is a optimization approach inspired by the innovative process seen in musicians aiming to achieve harmonious melodies.

HSA mimics the process of creating harmonious music by continuously improving solutions to optimization problems. Renowned for its simplicity, straightforward implementation, and efficacy in resolving issues. various optimization problems, including engineering design, parameter tuning, and scheduling. It provides a harmonious blend of exploring the search space and exploiting promising areas, making it suitable for a extensive of applications.

Initially, solution of the genetic algorithm is noted. From the initial memory for the Harmony Search Algorithm. Initially, define the objective function and constraints for the optimization problem. In a system, the objective function could aim to minimize system operating costs, maximize system stability. Constraints may include power balance, line flow limits, and generator limits. Its Objective function (J), which is same as (1).

Initialize the Harmony Memory, which stores a set of harmonies (random solutions). Each harmony represents a possible configuration of the interconnected power system. Initialize other parameters such as harmony memory size (HMS), harmony memory consideration rate (HMCR), pitch adjustment rate (PAR), and bandwidth (BW).

HMS=5
HMC=0.9
PAR=0.3
BW=0.001*ones (1, N)

Generate initial harmonies randomly within the feasible space i.e., the min and max defined by the problem constraints, with N=100.

Ensure that the generated harmonies satisfy the constraints of the system. Evaluate each harmony in the Harmony Memory using the defined J and constraints. Calculate the fitness value for every harmony based on its performance in optimizing the system.

Harmony Memory equation,

$$HM(i,j)=xmin(j)+rand()*(xmax(j)-xmin(j)) \quad (2)$$

Band Width equation,

$$B(j)=xmin(j)+rand()*(xmax(j)-xmin(j)) \quad (3)$$

First Memory history

$$1(i)=min(HM(:,N+1)) \quad (4)$$

Best memory best

$$1(ni)=min(HM(:,N+1)) \quad (5)$$

Define termination criteria to determine when to end the process. End criteria could include relaying a maximum iterations, getting a satisfactory solution, or reaching a predefined level of convergence.

If generated harmony is not a better solution, then generate a new harmony by combining elements from existing harmonies in the Harmony Memory. Randomly select elements from different harmonies with a probability determined by the HMCR. This encourages exploration of the search space. Apply pitch adjustment to the selected elements with a probability determined by the PAR. Pitch adjustment introduces small random changes to the selected elements, promoting exploitation of promising ranges of the search space.

Evaluate newly generated harmony using the J and constraints. Compare the fitness of recent harmony with the previous harmony in the HM. If the recent harmony is better than the previous harmony, replace that with the recent one. This maintains the best solutions found so far in the HM.

Iterate the process of generating new set of harmonies, evaluating them, and updating the HM until the End criteria are met.

Once the optimization process terminates, analyse the solutions stored in the HM Identify the best solution(s) that optimize the system according to the defined J and constraints. Interpret the optimized solution(s) and implement them in the actual power system to achieve improved performance, stability, or other desired objectives. The optimized solution after number of iterations, the PID Controller parameters derived from the Harmony Search Algorithm are.

K_p=-1.0000e-03 K_i=-0.5240 K_d=87.9542

The above procedure is given in the Flow Chart for the better understanding of the mechanism of the HSA in Figure 3 as.

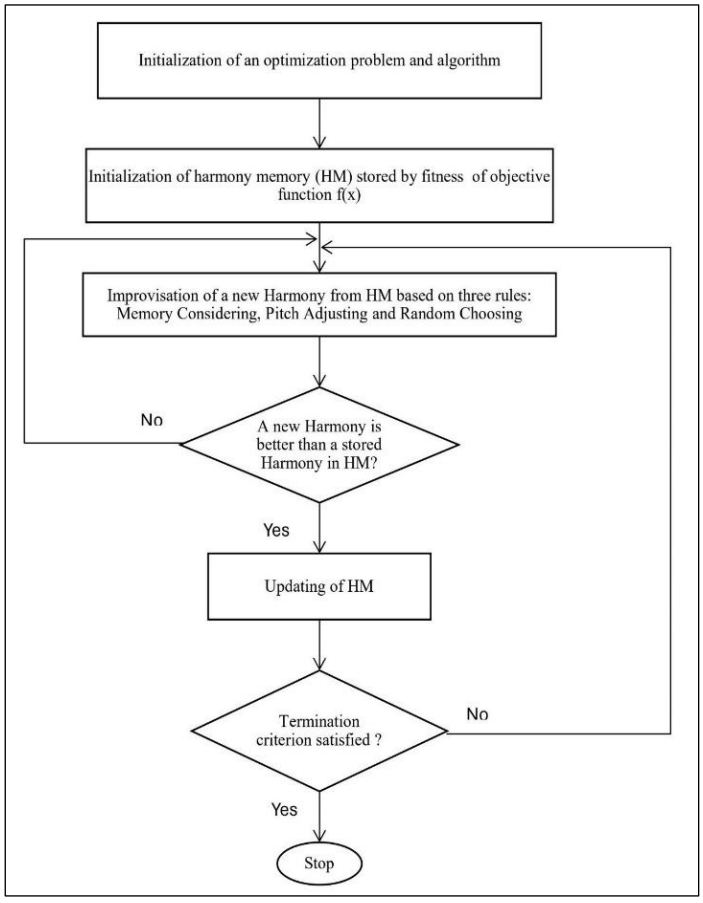


Figure 3: The flow chart of Harmony Search Algorithm.
Source: [11].

VII. RESULTS AND DISCUSSIONS

The input system considered is a two-area interconnected power system with area-1 input sources as thermal and wind integration and area-2 input sources as thermal only. For this system, a PID controller is introduced to stabilize the optimization problem with two algorithms as Genetic algorithm and Harmony search algorithm. Its simulation diagram is observed in fig from the MATLAB Simulation.

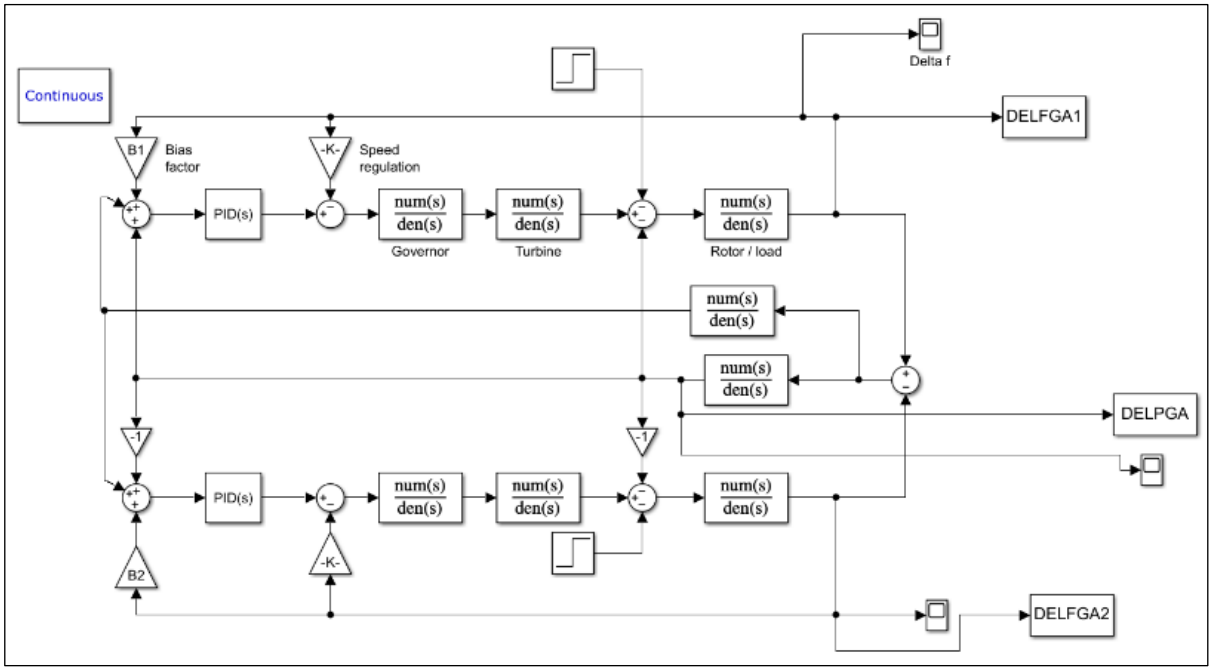


Figure 4: The Simulation Diagram of the power system.
Source: Authors, (2024).

Here, thermal input source is in the forms of a governor and a turbine by a first-order system transfer function and the wind sources in the form of a turbine by a first-order system transfer function. The respective nomenclature is observed from the figure 1 i.e., the schematic block diagram and its value respectively.

The response of this input system with area-1 as thermal with wind integration and area-2 as thermal only is observed through Conventional PID Controller, PID Tuning with Genetic Algorithm (GA) and PID Tuning with Harmony Search Algorithm (HSA) are three cases. They are.

Case-1: Nominal load conditions for the input system.
Case-2: Load with Wind distribution of +3% at 20s and -6% at 40s to the system.
Case-3: Nominal load with proportional gain (Kp) variations for +25% and -25% to its original value to the system

VII.1 CASE 1

The responses of the input system is observed for the nominal load with constant wind power as:

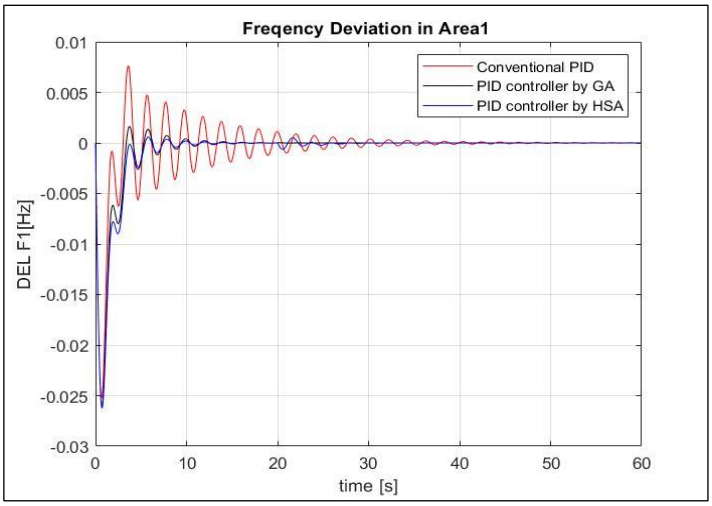


Figure 5: The system response to the load in area-1 incorporating wind integration.
Source: Authors, (2024).

From figure 5, the system response i.e., the frequency deviation between variables with the wind integration in the area-1 are observed with conventional PID, tuning with GA and HSA. From this it concludes that settling time (Ts) decreases from

conventional to hsa i.e., 40.8718 sec, 21.0701 sec and 18.9294 sec also Rise time (Tr) decreases from 1.43107 sec, 1.36484 sec and 1.29597 sec respectively. It shows that the input is stable when the pid controller tuning done by the harmony search algorithm than the other two scenarios. Its time domain specifications are shown in table 2.

Table 2: Comparative Analysis of area-1 in system with Conventional PID, GA based PID and HSA based PID.

S. N0	Parameter	PID	GA -PID	HSA-PID
1	Tr (sec)	1.4310	1.3648	1.2959
2	Ts (sec)	40.872	21.0701	18.929
3	Peak Overshoot	16.690	4.1725	2.0862

Source: Authors, (2024).

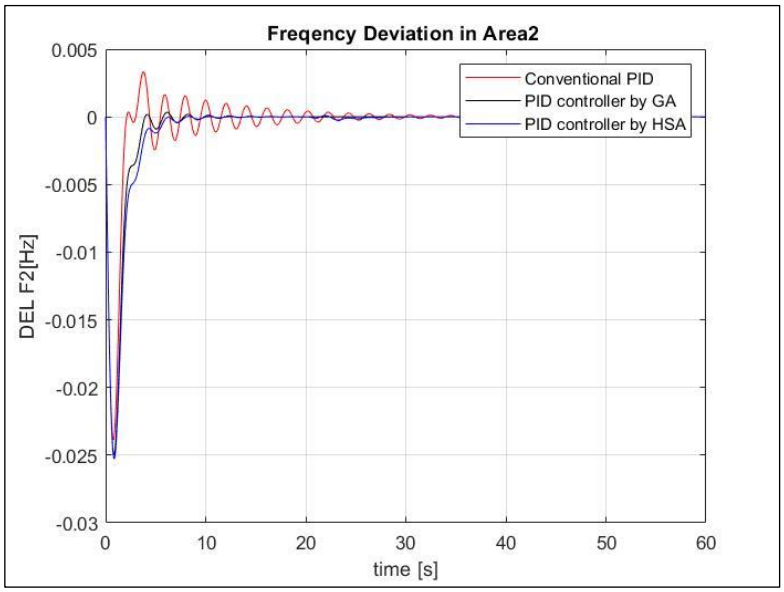


Figure 6: The system response of the load in area2 without wind unit.
Source: Authors, (2024).

From figure 6, the system response i.e., the frequency deviation between the input and output variables without the wind integration in the area-2 are observed with conventional PID, tuning with GA and HSA. From this it concludes that settling time (Ts) decreases from conventional to hsa i.e., 41.9282 sec, 20.1758 sec and 17.3359 sec also Rise time (Tr) decreases from 1.696466 sec, 1.41297 sec and 1.29597 sec respectively. It shows that the input is stable when the pid controller tuning done by the harmony search algorithm than the other two scenarios. Its time domain specifications are shown in table 3.

Table 3: Comparative Analysis of area-2 in system with Conventional PID, GA based PID and HSA based PID.

S. N0	Parameter	PID	GA -PID	HSA-PID
1	Tr (sec)	1.6947	1.4129	1.296
2	Ts (sec)	41.928	20.176	17.336
3	Peak Overshoot	19.619	4.6925	2.4275

Source: Authors, (2024).

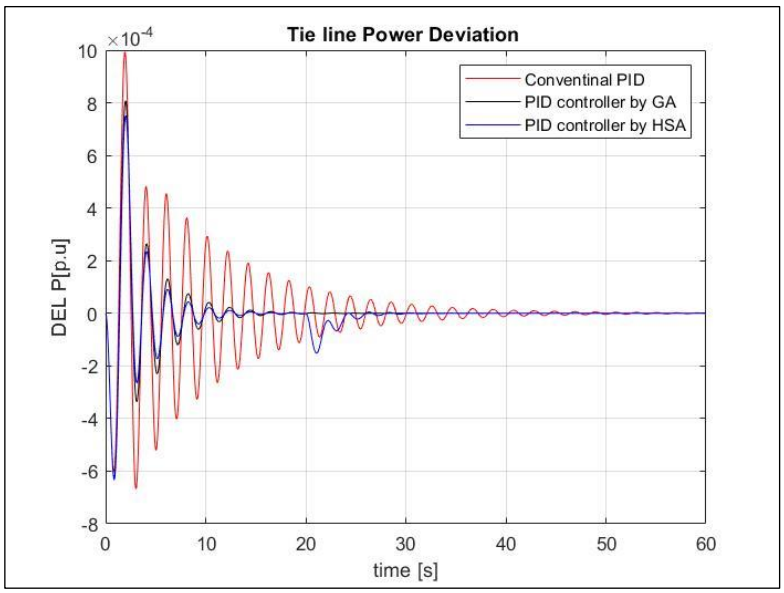


Figure 7: The response of the system with the tie line power change between two areas.
Source: Authors, (2024).

From figure 7, the system response of tie line power deviation which is the frequency deviation between the area-1 and area-2 where area-1 with wind integration and area-2 without wind integration settles at settling time (Ts) which decreases from conventional to hsa i.e., 52.4927 sec, 32.1967 sec and 19.8815 sec also Rise time (Tr) decreases from 1.69466 sec, 1.58744 sec and 1.5012 sec respectively. It shows that the input is stable when the pid controller tuning done by the harmony search algorithm than the other two scenarios. Its time domain specifications are shown in table 4.

Table 4: Comparative Analysis of Tie line power deviation in system with Conventional PID, GA based PID and HSA based PID.

S. N0	Parameter	PID	GA -PID	HSA-PID
1	Tr (sec)	1.6946	1.5874	1.5012
2	Ts (sec)	52.4927	32.1967	19.882
3	Peak Overshoot	45.8114	30.876	29.645

Source: Authors, (2024).

VII.2 CASE 2

Incorporating wind power into the power system often leads to an increase in relative frequency oscillations, attributed to the distinct characteristics of wind. To evaluate the enhancements in controller performance compared to conventional controllers, an initial investigation is carried out on a system with consistent wind unit. This scenario closely mirrors a system without wind unit in either area. In this situation, two load perturbance are assessed, and output responses are compared to demonstrate effectiveness of the controller.

Figure 8,9 &10 illustrates the performances of the three controllers amidst load changes and variations in wind penetration in area1. Two variations are observed in area1, encompassing wind perturbation of +3% at 20 s and -6% at 40 s, alongside output fluctuations. Among all the tuning methods, the HSA based controller exhibits superior performance in reducing system frequency oscillations, even when confronted with wind-induced disturbances. Conversely, the signals produced by the other two demonstrate relatively lower efficacy. The parameters optimized for each controller are drawn below.

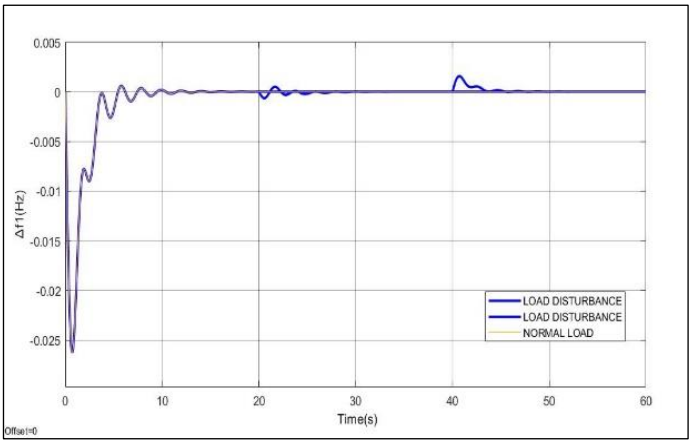


Figure 8: The system response to the load in area-1 incorporating wind integration.
Source: Authors, (2024).

From figure 8, the system response i.e., the frequency deviation between the input and output variables with the wind integration in the area-1 is observed at load changes and wind disturbances of+3% at 20s and -6% at 40s. From this it can be stated that even in the disturbances the input system is stable after oscillating from the short term of time. Its settling time is obtained as 49.95 sec while the normal load settled as 18.9294 sec.

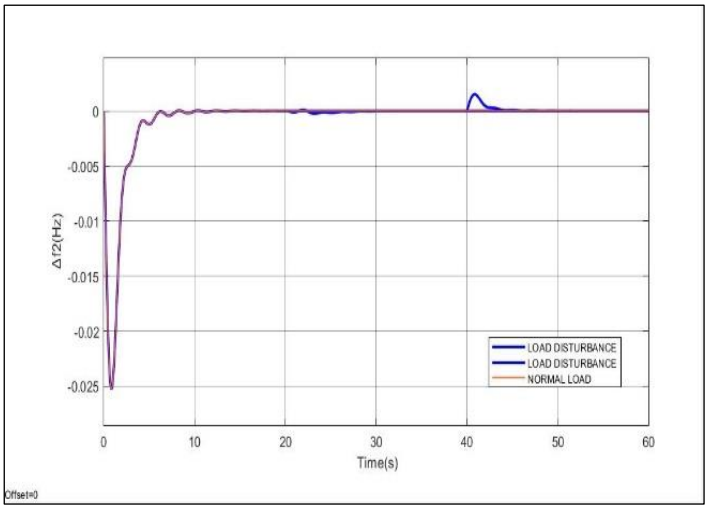


Figure 9: The system response of the load in area2 without wind unit.
Source: Authors, (2024).

From figure 9, the system response i.e., the frequency deviation between the input and output variables with the wind integration in the area-1 is observed at load changes and wind disturbances of+3% at 20s and -6% at 40s. From this it can be stated that even in the disturbances the input system is stable after oscillating from the short term of time. Its settling time is obtained as 46.99 sec while the normal load settled as 17.33359 sec.

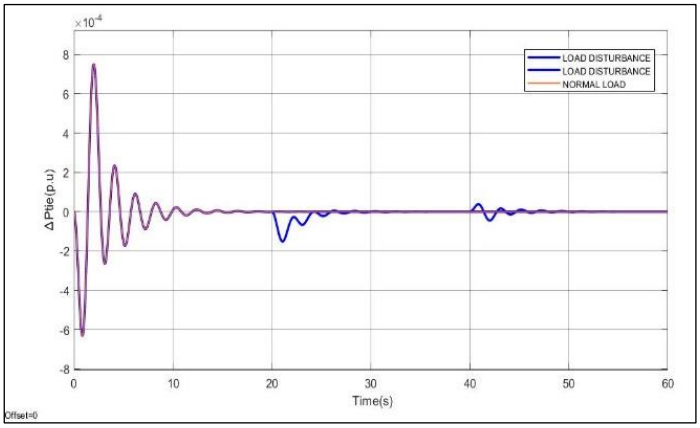


Figure 10: The response of the system with the tie line power change between two areas.
Source: Authors, (2024).

From figure 10, the system response of tie line power deviation is observed at load changes and wind disturbances of+3% at 20s and -6% at 40s. From this it can be stated that even in the disturbances the input system is stable after oscillating from the short term of time. Its settling time is obtained as 50.95 sec while the normal load settled as 19.8815 sec.

VII.3 CASE 3

In this instance, we are evaluating the impact of varying system parameters on the output response of the system. Out of all parameters, system gains, and time constants display notable

variability owing to the dynamic characteristics of these parameters during operation. However, upon integrating the controller into the control loop of the interconnected power system, the variations in parameters become insignificant. The subsequent figures depict the frequency variations in controller gains fluctuate by +25% and -25%.

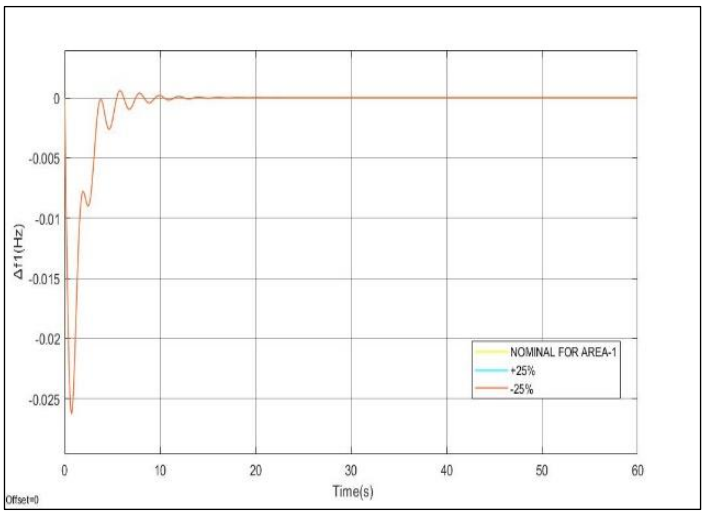


Figure 11: The system response to the load in area-1 incorporating wind integration.
Source: Authors, (2024).

From figure 11, the system response i.e., the frequency deviation between the input and output variables with the wind integration in the area-1 with +25% and -25% of proportional gain (Kp) variation in the pid controller settles at settling time (Ts) 17.3359sec same as the nominal pid controller as well as the rise time (Tr) 1.29597sec which shows that the system is stable for the gain disturbances also.

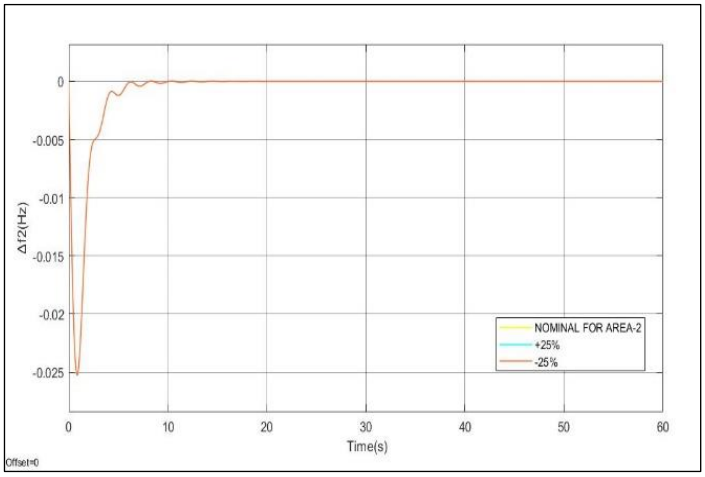


Figure 12: The system response of the load in area2 without wind unit.
Source: Authors, (2024).

From figure 12, the system response i.e., the frequency deviation between the input and output variables without the wind integration in the area-2 with +25% and -25% of proportional gain (Kp) variation in the pid controller settles at settling time (Ts) 19.8815sec same as the nominal pid controller as well as the rise time (Tr) 1.5012sec which shows that the system is stable for the gain disturbances also.

VIII. CONCLUSIONS

Based on the constraints of the conventional controller applied to system, a new algorithm-based tuning (GA, HSA) for the controller is observed its output responses and the system output performance for disturbances. From these observations, it can conclude that the system's performance is superior when utilizing a PID controller tuned by the Harmony Search Algorithm, exhibiting reduced peak overshoot and shorter settling time. The robustness of the system is verified by adjusting both the load and the Kp of the controller, demonstrating the system's inherent robustness. In summary, the PID controller fine-tuned by the Harmony Search Algorithm emerges as the optimal option for LFC applications, particularly in systems integrated with renewable power sources, ensuring stable frequency and power flows. Through case studies, it is observed that for the load variations and controller parameter variations, the system is robust in nature. For further study on this system, Hybrid Intellectual Control Mechanisms can be implemented.

IX. AUTHOR'S CONTRIBUTION

Conceptualization: Gottam Venkata Supriya, M Ramasekhara Reddy and P Bharat Kumar.
Methodology: Gottam Venkata Supriya, M Ramasekhara Reddy and P Bharat Kumar.
Investigation: Gottam Venkata Supriya, M Ramasekhara Reddy and P Bharat Kumar.
Discussion of results: Gottam Venkata Supriya, M Ramasekhara Reddy and P Bharat Kumar.
Writing – Original Draft: Gottam Venkata Supriya.
Writing – Review and Editing: Gottam Venkata Supriya, M Ramasekhara Reddy and P Bharat Kumar.
Resources: M Ramasekhara Reddy and P Bharat Kumar.
Supervision: M Ramasekhara Reddy and P Bharat Kumar.
Approval of the final text: Gottam Venkata Supriya, M Ramasekhara Reddy and P Bharat Kumar.

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RESEARCH ARTICLE OPEN ACCESS

PROGRESS IN THE WELDING OF AL ALLOY THIN SHEET AND FUTURE PROSPECTUS FOR AUTOMOBILE

Sachindra Doshia*[1], Vaghosi Ketan[2] and N D Mehta[3]

[1, 2, 3] Mechanical Engineering Department, Government Engineering College Bhavnagar, Gujarat, India.

[1] http://orcid.org/0000-0002-6340-9407, [2] http://orcid.org/0000-0002-5849-2883, [3] http://orcid.org/0009-0000-3083-9008

Email: *professordoshi@gmail.com, vaghosiketan@gmail.com, nirav.mehta248@gmail.com

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ABSTRACT

Since the early 21st century, the automotive and aluminium industries have rapidly developed a variety of advancements in response to competitive, environmental, and technological problems. Reduction in tare weight of vehicle is one approach for dealing with some of these problems. Al alloys have potential to save mass, which is need for fuel efficiency, environment pollution and emerging electrical vehicle. The estimated consumption of Al alloy in vehicle by 2025 is 250 Kg from current 180 Kg. However, the difficulties in welding Al alloy have hindrance their widespread adoption. Al alloys, which are regarded as being challenging to fuse using a traditional process because of its intrinsic qualities, such as its low melting point, high thermal conductivity, high solubility in hydrogen, formation of oxides, and significant solidification shrinkage. Currently low heat input welding process such as MIGW, TIGW, FSW, LBW and EBW are employed by industries for thin sheet Al alloy. However, each of these techniques' variants suffers from few limitations. Therefore, joining of Al alloy thin sheet is still a difficult and costlier task. Weld beads frequently exhibit many defects which significantly lower the mechanical and fatigue strength of thin Al alloy sheets. This overview aims to provide a concise summary of current advancements in the joining of Al alloys and shows the future prospectus and direction of development in joining of thin sheet Al alloy. The researchers working on joining Al alloys are also intended beneficiaries of this study.

I. INTRODUCTION

The third most prevalent element in the Earth's crust is Al [1]. Al is distinguished by its appearance, lightweight, formability, specific strength, and corrosion resistance. Some Al alloys AA7075 is stronger than structural steel. These remarkable qualities make this metal and its alloys the most cost-effective and appealing option for a wide range of applications, particularly when lightweight is required especially in automobiles, aerospace vehicle etc…

The first time Al alloy sheet was utilized for a hood was on the Japanese Mazda RX-7 in 1985. Al alloy sheets were later used in sports cars and opulent sedans. In automobiles most suitable Al alloys are 5000 and 6000 series. However, 6000 series Al alloys are employed more for automotive sheet metal as their strengths can easily be controlled by heat treatments. Nowadays Al alloy is used in various automobile body sheet metal such as hoods, trunk lids, outer panels, doors and protection covers including heat insulators. Usage of Al alloy in automobiles is increasing exponentially in order to be competitive and satisfy stringent environmental regulations and government norms.

Al alloy has a much wider range of applications because its higher formability due to its face centered cubic crystal structure (FCC), which has an abundance of alternative slip systems. At all temperatures up to the melting point, Al alloys have a FCC structure. As a result, they do not undergo an allotropic phase shift during welding, and their hardness in the heat-affected zone normally remains constant (HAZ). Al may be bonded using a variety of techniques such as fusion and resistance welding, brazing, soldering,

adhesive bonding, and mechanical methods such as riveting and bolting. Al alloy has processing qualities that are vastly different from those of the more common material steel, its use in the automotive industry is restricted [2].

Modern automobiles include a variety of body panels made of aluminium alloy, including hoods, bumper, fender, radiator, exterior panels, doors, and protective coverings like heat insulators as shown in Fig. 1. Additionally, in order to remain competitive and adhere to strict environmental rules and governmental standards, the use of aluminium alloy in vehicles is growing tremendously. Moreover, the switch from gasoline engines to electric engine is one of the most significant transformations in the automotive sector. These cars may benefit from aluminum's thermal characteristics and high strength/weight ratio. Automobile manufacturers are dealing with a number of difficulties as they switch to electric vehicle system. According to estimates from Ducker Worldwide Europe on the use of aluminium in vehicles, consumption increased from 120 kg to 180 kg per car over the past ten years, and it is anticipated to reach up to 225 kg per vehicle by 2025 as shown in Fig. 2. [3].

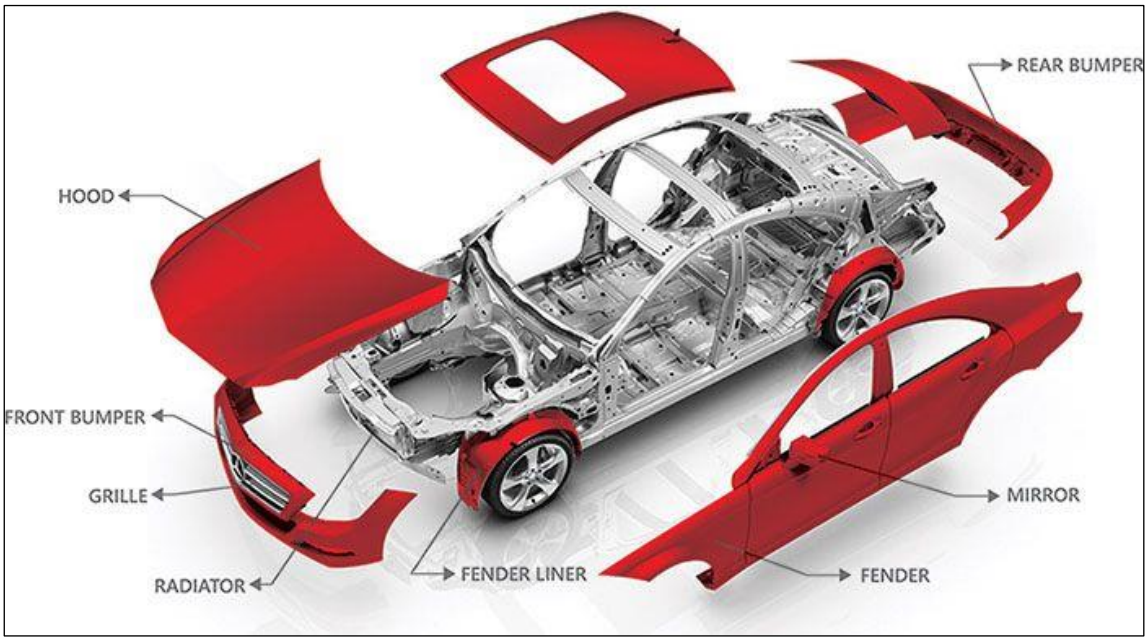

Figure1: Usage of Aluminum alloy in modern car.
Source: Authors, (2024).

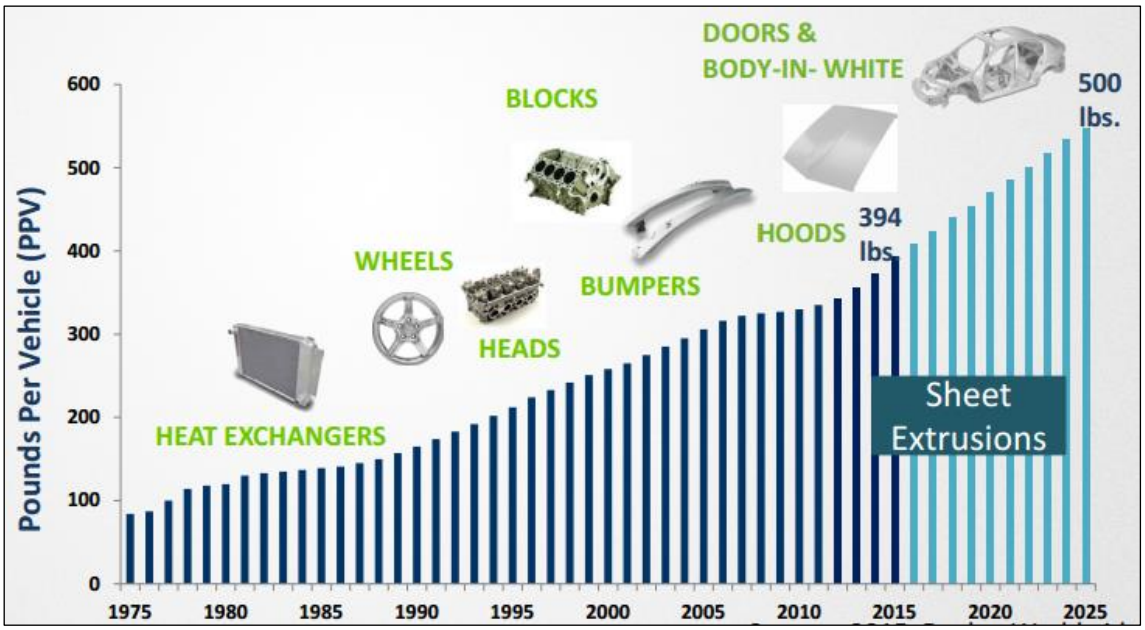

Figure 2: Usage of Aluminum alloy in Vehicles.
Source: [3].

The 5000 and 6000 series of aluminium alloys are best for use in cars. However, since they are heat-treatable and their strengths are easily regulated by heat, 6000 series aluminium alloys are used more for car panels.

5xxx Series Alloys are Al-Mg alloys. They have the highest strength of the thermally non-strengthened alloys. It is also easily welded and has a wide range of uses. They are used in shipbuilding, transportation, pressure vessels, bridges, and construction. The

magnesium content, and service circumstances of the welded component, is taken into consideration when choosing the filler alloys. Because of their propensity for sensitization and subsequent susceptibility to stress corrosion cracking, alloys in this series with more than 3.0% magnesium are not advised for elevated temperature service above 66°C.

6xxx series alloys are Al-Mg-Si alloys. They can be found all across the fabrication industry. They are frequently utilized as extrusions and are a part of many structural works. Mg and Si are added to Aluminium to form the compound magnesium-silicide, which gives this material the capacity to undergo solution heat treatment for increased strength. These alloys shouldn't be arc welded without filler material since they are naturally susceptible to solidification cracks. To provide dilution of the base material and avoid the hot cracking issue, sufficient volumes of filler material must be added during the arc welding process.

The automotive manufacturers presently use thin sheet of aluminum alloy of 5000 and 6000 series ranging from 0.6-1.8mm. The thickness of aluminum sheet in various automobiles can vary depending on a number of factors, including the specific part of the car, the desired strength and weight, and the manufacturing process. However, in general hood and trunk use thicker aluminum sheets, around 1.2-1.6mm, for rigidity and dent resistance, whereas doors and fenders are often use slightly thinner sheets, around 0.8-1.2mm, to balance strength with weight and formability. Least thickness is used in roof and quarter panels, which may use even thinnest sheets, around 0.6-0.8mm, for weight savings and easier shaping. Al alloy sheet thickness is maximum in inner structural components like chassis and floor pans, which is around 1.5-2.0mm, for high strength and stiffness.

II. WELDABILITY OF ALUMINUM ALLOY

A weldment is a zone comprising the weld bead, HAZ, and the adjacent base metal. Ideally, a weldment should have the same properties as the base metal. In actuality, When an Al alloy is welded, it can generate a number of faults since aluminium is not a lenient alloy like steel. Weld beads frequently exhibit hot tearing, hardening fissures, porosity, deformation, and melt-through during welding because of adverse welding characteristics of Al alloy as shown in Fig. 3. These flaws significantly lower the mechanical and fatigue strength of Al alloy sheets.

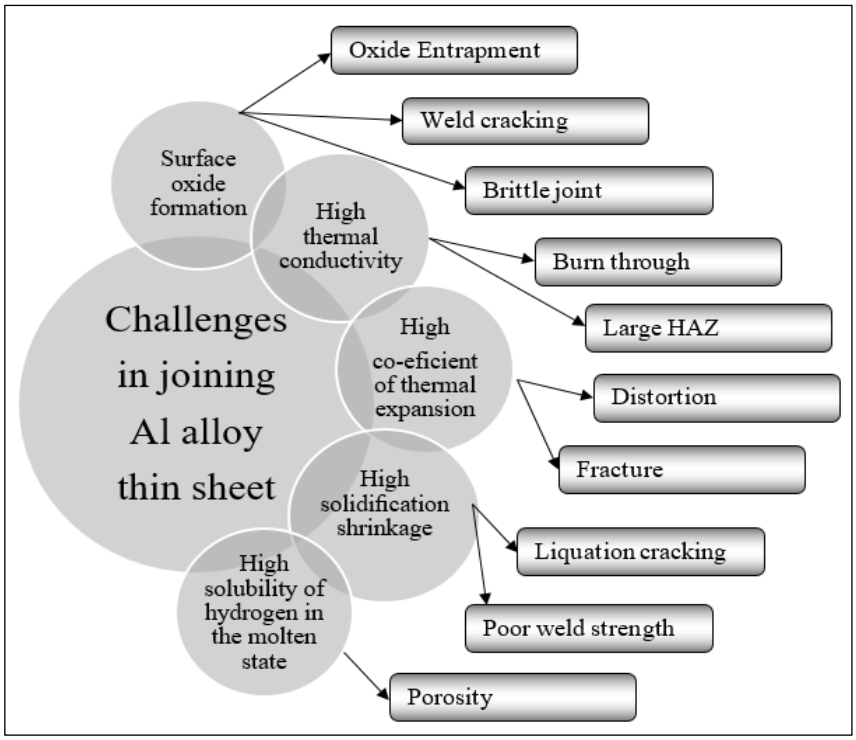

Figure 3: Challenges of joining Al alloy.
Source: Authors, (2024).

The protective oxide coating that exists on Al alloy prevents corrosion but may also hinder welding. The oxide layer over the Aluminium is very strong. When Aluminium surfaces are exposed to air, a thick coating of Al oxide develops rapidly and keeps growing. To create defect-free Al fusion joints, this oxide layer must be removed manually using machining, filing, wire brushing, scraping, or chemical cleaning. Even after chemical cleaning of the sheet surface, within a microsecond, it develops a nano-layer of Al oxide.

Cathodic cleaning during direct current electrode positive (DCEP) MIGW or AC TIGW is an alternate method for eliminating surface oxide. If strong oxides layer is present then oxide pieces may have entrapped in the fusion zone, causing brittle joint, fusion failure, and weld cracking. The oxide must be prevented from re-forming during welding by protecting the joint region with a shield of non-oxidizing gas such as argon, helium, hydrogen or chemically by use of fluxes [4].

Thermal conductivity is the most important physical factor influencing weldability. Al alloys have roughly half the thermal conductivity of copper and four times the thermal conductivity of low-carbon steel. This means that heat delivered four times as quickly to Al alloys as steel for the same amount of heat flux. This resulted in to burn through during joining. Low heat input is key to join Al alloy. However, the strong heat conductivity of Al alloys aids in the solidification of the molten weld pool of Al, allowing for out-of-position welding [4].

High coefficient of thermal expansion, causing distortion is

important physical attribute to consider when discussing weldability. As it is the change in length of a material as its temperature changes [5]. Aluminium has a coefficient thermal expansion that is twice of steel. As a result, it may result in to fracture development caused by shrinkage blockage and significant distortion after welding if proper heat source parameter is not chosen. This means that the heat input during joining should be maintained to a minimum [5].

A high coefficient of thermal expansion combined with a high thermal conductivity would result in considerable distortion of Al during welding. Use of thick copper backup plate and tack weld will reduce distortion [4].

For Al alloys, wide solidification temperature range resulted in to poor weld bead strength and liquation or hot cracking. In contrast, melting range is significantly lower than for copper or steel. It demands controlled heat input and higher solidification time [4].

Another challenge for resistant welding of Al alloy is its good electrical conductivity. Al alloy is good electricity conductor and therefore it requires significantly greater current during resistant welding. This demand higher rated machines for welding Al alloy sheet compare to present automotive material steel and increased the cost of joining.

Porosity is common in Al alloys weld bead as Al alloy have high hydrogen solubility when liquid. If the weld pool absorbs hydrogen during fusion joining from ambient humidity and surface contamination, then supersaturated hydrogen form bubbles during cooling. These bubbles cannot escape the weld pool before solidification; they will produce pores in the weld [3].

The question of which welding process is the best and most cost-efficient for joining sheets of Al alloy arises as several welding procedures are available. There is no simple solution to this problem. This is because the selection of a welding method is dependent on several variables, such as the base metal, whether welding is indoor or outdoor, welding rate, filler material utilization, the thickness of metal, etc... Yet, several researchers have made significant contributions by contrasting the effectiveness of various welding methods.

Welding techniques for Al alloys are quite similar to those for replaced structural material steel. However, joining difficulties and defect rate is very high compared to steel owing to discussed adverse properties of Al alloy. Major joining techniques used for Al alloy are mentioned in Fig. 4 apart from mechanical fastening (Riveting) and adhesive bonding. These all techniques suffer from major and trivial problems as mentioned below.

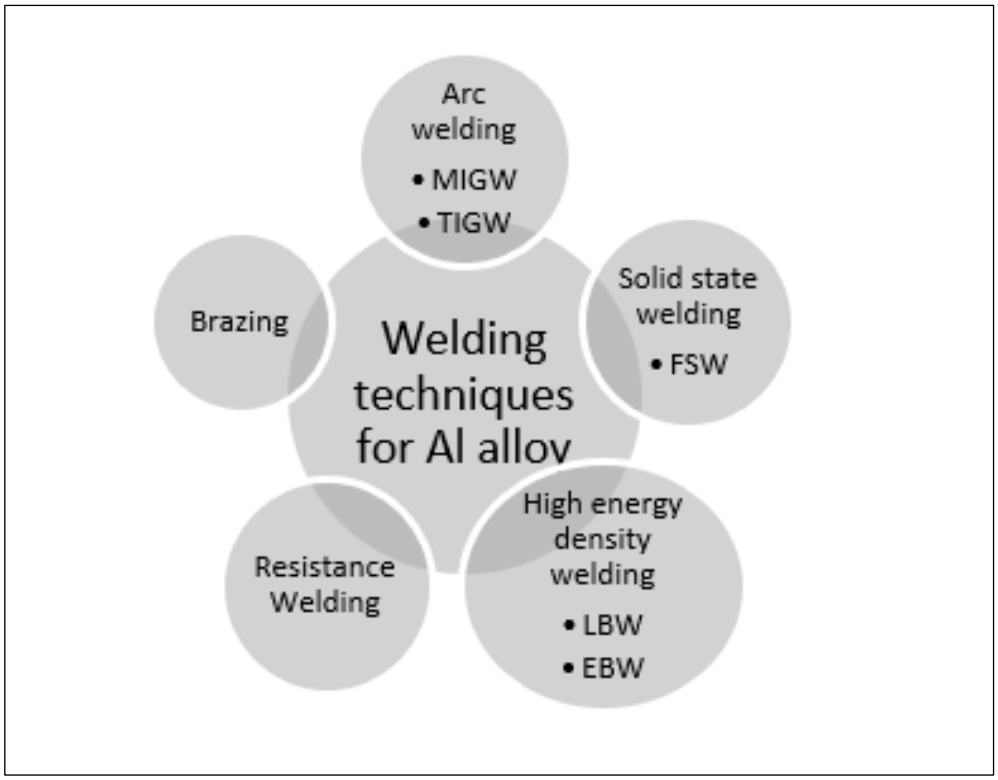

Figure 4: Permeant joining techniques of Al alloy.
Source: Authors, (2024).

Factors that cause weld deficiencies must be carefully addressed if industries are to achieve their quality criteria while meeting a high-volume production demand. However, various welding processes were developed in last two decades for Al alloy because its physical, mechanical, and other qualities differ from those of substituted material steel. Notable developments in Al alloy welding techniques as a result of its commercialization have significantly solved the limitations associated with Al alloy welding like oxide film removal, sound weld bead and HAZ. [8]. Variants of MIGW and TIGW process showed good results through controlled heat input during joining of Al alloy and look promising for economical joining especially for automobile panels [7].

III. WELDING TECHNIQUES FOR AL ALLOY THIN SHEET

III.1 TIG WELDING AND MIG WELDING OF AL ALLOY THIN SHEET

TIGW and MIGW are often used in the industry to connect Al alloys and related alloys; for instance, MIGW is used in the fabrication of automobile bodies. The only Al alloys that may be used for this application are those that cannot be heated. During welding the controlled heat input delivered to the material during joining may cause the evaporation of low melting poin t solute

atoms in the fusion zone that causes a loss of strength. The use of suitable filler wires containing alloying additives, the quantity of which decreases owing to evaporation, can reverse this loss of strength in the fusion zone of non-heat-treatable Al alloys [9]. This is especially true for non-heat-treatable alloys like Al alloy, where solid solution strengthening is crucial.

The excellent thermal conductivity caused large HAZ with overaging. It is common in fusion joining of these alloys as a result of excessive heat input leading to loss of strength in this region. The large weakened HAZ in heat-treatable Al alloys is more evident when the heat input is more [10].

Al alloys can be joined using the regulated heat input of the MIGW method, but its use is constrained by challenges with the steady and controlled metal transfer. Although a high welding current offers a consistent spray mode, it also generates more heat, which must be managed by the welding speed. As a result, researchers have created a wide variety of GMAW procedures since the 1980s that make use of the advantages of the MIGW process and do away with its inherent drawbacks. The graphic below in Fig. 5 provides an overview of the MIGW process variations [11].

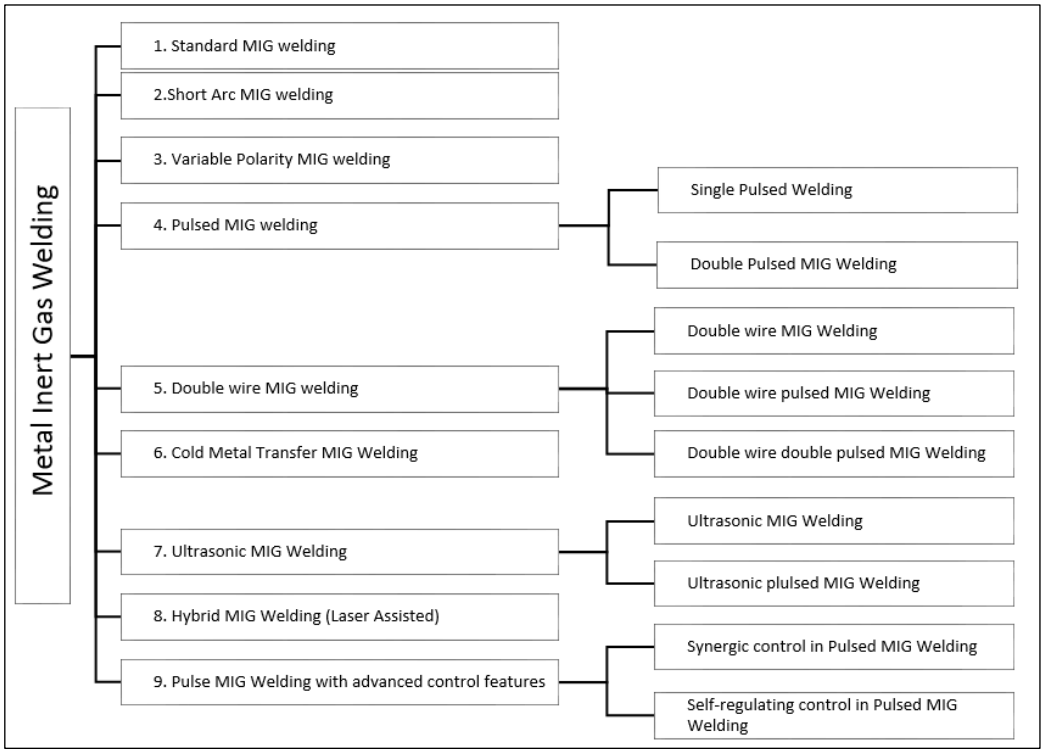

Figure 5: Different types of MIGW process.
Source: [11].

As mentioned above, the weldability of heat-treatable Al alloys has been researched using low heat input techniques through variations of the MIGW process such as pulsed MIGW and cold metal transfer (CMT) MIGW [11-13]. Due to its low heat input, like in FSW, this fusion joining technology provides the opportunity to fusion joint any Al alloys thin sheet of 6xxx and 7xxx series alloys. Comparing this approach to FSW, MIGW is simpler, more adaptable, and quicker [14]. Many studies proved that compared to conventional MIGW and FSW, pulsed MIGW and CMT MIGW offer greater joint tensile strength and ductility [9]. In comparison to conventional MIGW processes, CMT MIGW and pulsed MIGW offer reduced thermal heat input, gap bridging capability, low dilution, quick operation, and little spatter, making it particularly appealing and promising for combining such challenging Al alloys [8].

TIGW and MIGW are often used in industry to fabricate steel automobile bodies. But during the welding of an Al alloy thin sheet, the controlled heat input delivered to the material during joining may cause the evaporation of low melting point solute atoms in the fusion zone that causes a loss of strength. The use of suitable filler wires containing alloying additives, the quantity of which decreases owing to evaporation, can reverse this loss of strength in the fusion zone of non-heat-treatable Al alloys [9]. This is especially true for non-heat treatable alloys like Al alloy, where solid solution strengthening is crucial. The excellent thermal conductivity caused large HAZ with overaging. It is common in the fusion joining of Al alloys as a result of excessive heat input leading to loss of strength in this region. The large weakened HAZ in heat-treatable Al alloys is more evident when the heat input is more [10].

Al alloys can be joined using the regulated heat input of the MIGW method, but its use is constrained by challenges with the steady and controlled metal transfer. Although a high welding current offers a consistent spray mode, it also generates more heat, which must be managed by the welding speed. As a result, researchers have created a wide variety of GMAW procedures since the 1980s that make use of the advantages of the MIGW process and do away with its inherent drawbacks [11].

The weldability of heat-treatable Al alloys has been researched much using low heat input techniques through variations of the MIGW process such as pulsed MIGW (P-MIGW) and cold metal transfer (CMT) MIGW [11-13]. Due to its low heat input, like in FSW, this fusion joining technology provides the opportunity to fusion join any Al alloys thin sheet of 6xxx and 7xxx series. Comparing this approach to FSW, MIGW is simpler, more adaptable, and quicker [14]. Many studies proved that compared to conventional MIGW and FSW, pulsed MIGW and CMT MIGW offer greater joint tensile strength and ductility [9,14,34-35]. In

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As the cutthroat competition in the automobile sector keeps manufacturers tight on the production cost. Therefore, in the domestic and economic automobile sector use of Al alloy sheets is hindered, because of its higher investment and production cost compared to steel. The welding of thin Al alloy sheet by conventional arc welding process especially P-MIGW with controlled heat input and correct use of filler wire looks promising

It was reviewed from the literature that P-MIG welding is a complex process and sound weld beads without any defects primarily depends on the selection and control of various welding process parameters. The pulsing creates spray transfer which resulted in low heat input during the welding process, without negotiating welding speed. Especially welding process parameters significantly influence the quality of weld beads compared to electrode parameters. An optimum combination of these pulse parameters only resulted in a defect-free sound weld bead [37-40].

III.2 HIGH ENERGY DENSITY WELDING

Using high-power density fusion joining procedures, such as laser beam welding (LBW) or electron beam welding (EBW), is another approach to reduce the amount of heat supplied during fusion welding [8, 14-16]. LBW and EBW use a highly concentrated heat source. Therefore, there is relatively little total heat input delivered to the workpiece. That is resulted in to very narrow fusion zones and very small HAZ area is formed. It reduced distortion and residual stresses significantly. EBW provides more sound weld bead without oxide formation and porosity as welding carried out in vacuum. Reflectivity of Al alloys demand extra care during LBW. As LBW and EBW process leads very little HAZ, there is not change in hardness in thin sheet around fusion zone. It was also noted, thin sheets welded by EBW and LBW showed no microstructural alteration, and consequent base metal deterioration in the HAZ area compared to MIGW and TIGW, which involves larger heat input during welding. [15] Many variants of EBW and LBW process are developed for sound weld of Al alloy. However extensive research needs to be carried out for reducing high capital cost of such process. As the cut throat competition in automobile sector keeps manufacturer tight on the production cost. Therefore, in the domestic and economical automobile sector use of Al alloy panel is hindered, because of its higher investment and production cost compared to steel.

III.3 FRICTION STIR WELDING

Low heat input during Al alloy joining keeps material deterioration to a smaller level. That is resulted in to greater joint performance. Unlike fusion welding processes, Friction stir welding (FSW)methods often result in joints with higher joint performance because of less heat input during the process. Since development of FSW process in 1991, it showed significant advancement in joining light metal alloys with higher thermal conductivity. [4] Currently, many FSW variants are developed to provide more symmetrical heat input. These are used to butt joints with enhanced joint properties in a shipbuilding, high-speed trains, automobiles and the aviation industry [17-20]. FSW is a contender to take the place of traditional resistance spot welding as well as fusion welding, which is frequently employed in the automobile sector [21]. High electrical conductivity poses challenge in resistance welding of Al alloy thin sheet, is effectively accomplished with FSW. As a result, this will enable the use of lightweight Al alloys in the production of automobiles.

During FSW of Al alloy it was noted by many researchers that the loss of strength brought on by precipitate dissolution and coarsening in these high strength alloys cannot be entirely recovered by grain refining, leading to typically significantly poorer joint efficiencies. [22-23]. AA 6061-T6 and AA 7075-T6 alloys with FSW have been reported to have maximum joint efficiencies of 75 and 80%, respectively. However, following solution heat treatments, these joint efficiency values were recovered to about 90% and 100%. [24-25] FSW variants like external and in-process cooling through compressed air, water, under water FSW or use of liquid nitrogen is researched to limit heat input during joining such highly thermally conductive alloys. Such experiments showed a viable way to increase the strength and hardness of joined sheets. [26-30]

Despite of such advantages, it was mentioned that Al alloy joint prepared by FSW do not offer any advantages over fusion welded joint with respect to the strength of the WZ. FSW process resulted in substantial strength loss in the WZ unless the weld parameters are not properly regulated. [31]

Controlled heat input and correct use of filler wire resulted in significant recovery of strength during MIGW and TIGW. Such recovery is not possible in FSW.

During low heat input welding techniques such pulsed MIGW, pulsed TIGW, CMT MIGW, LBW or EBW the Al alloy deterioration in the WZ and HAZ is not as substantial. [14,16] However, it is important to note that by adopting the ideal weld settings, the amount of strength loss in FSW may be reduced.

FSW has significant shortcomings like automotive thin sheet applications often require joining of curved surfaces and intricate features, which cannot yet be welded with FSW. Moreover, the slow welding speed and lack of process flexibility caused by the need for work piece clamping and access is another major hindrance.

IV. OVERALL THOUGHTS

Despite its many benefits and inherent flexibility of high energy rate welding, the broad application of it's in the automotive industry has been severely limited by the high capital cost of laser equipment.

Good thermal conductivity of Al alloy demand more often dressed tips and costlier, higher rated, larger equipment, which limits resistance spot welding application in spite of significant benefits.

Automotive thin sheet applications often require joining of curved surfaces and intricate features, which cannot yet be welded with friction stir welding.

The weld quality and weld shape in TIGW and MIGW are significantly impacted by the heat input, controlled heat input and stringent control of heat source parameter is essential for sound weld bead [6].

MIGW and TIGW is effectively used in automobile industry to combine Al alloys thin sheet, such as when building automotive panels. However, formation of severe and large HAZ causes strength loss. Recent in-depth studies on the weldability of Al alloys have demonstrated that these alloys may be effectively connected using low heat input arc welding techniques such pulsed MIGW and CMT MIGW.

Furthermore, joints in Al alloys, may be produced using low heat input, high energy density welding techniques like LBW and EBW. High energy density welding process supplied, concentrated low heat input. In such methods loss of strength occurring in the FZ may be reversed to very near base alloy strength by utilizing the

proper filler wire. Although the strength loss in the HAZ cannot be prevented, its severity can be reduced by using modest heat input. Al alloy can be joined by pulsed MIGW, CMT MIGW, EBW and LBW provided that the heat input is kept sufficiently low and adequate filler alloys is used.

Additionally, it is widely known that FSW has a lot more promise for connecting Al alloys than fusion welding does because FSW does not always result in a loss of strength in the joint area. Due to the dynamic recrystallization in this instance, FSW only causes the formation of recrystallized grains in the weld area. Heat treatable Al alloys showed considerable decrease in strength in FZ and HAZ is one of the major hindrance in application of FSW. Generation of residual stresses in HAZ degrade material strength. It is common in all welding techniques. However, compared to fusion welding, the degree of residual stress is less severe in FSW. Therefore, overall strength of welded thin sheet is more in FSW compared to fusion welding techniques. Especially, FSW with in process cooling, which kept low heat input provide better joint efficiency with less degradation in base metal. For joining Al alloy thin sheets, currently FSW impressively used by industries. In-depth research is now being done to determine whether FSW can be used to connect curved sheets and intricate shapes with higher speeds.

The use of aluminum in electric vehicles (EVs) is particularly promising, as their heavier battery packs necessitate weight reduction in other areas. Sustainability is another key aspect of aluminum's appeal. It's highly recyclable, with over 70% of all ever-produced aluminum still in use today. Any advancements made in the mass manufacture of light transportation systems and, consequently, a considerable decrease in fuel consumption will be made in the friction stir butt and spot welding of Al and Mg alloys, especially in incompatible combinations.

V. FUTURE OUTLOOK

The aluminum market for the transportation industry has grown significantly during the past few years. Parts made of aluminum have primarily been used in high-end cars. Future trends indicate that aluminum usage will continue to flourish, with applications in the low-cost auto and aviation sectors.

Aluminum can be up to 60% lighter than steel, the traditional king of car bodies. This translates to significant fuel savings, with estimates suggesting a 5-10% reduction in fuel consumption for vehicles with increased aluminum content.

Lighter cars also mean lower emissions, making aluminum a vital player in the fight against climate change. The International Aluminium Institute estimates that widespread aluminum adoption in cars could cut global CO2 emissions by 660 million tonnes by 2050 and will address environmental challenges. Steel will be replaced by lighter materials including aluminium and magnesium, as the most cost-effective way to do this. In the long run Aluminum, magnesium and polymers may replace steel completely in automotive and aviation application [32].

In the high energy density welding processes, LBW looks promising as it provides accurate, effective and concentrated formation of weld bead. But, it is necessary to mitigate major issue of aluminum poor energy absorption capability. In the near future variants of MIGW like pulsed MIGW and CMT MIGW controlled low heat input, process flexibilities, easy automation and use of filler wire provides good quality weld bead with good structural strength of thin sheet joint.

The variant of FSW process like laser assisted FSW may be explored by industries in the near future. Prominent features of FSW with further advancement in process may allowed for the design and production of automobiles using lighter materials like Al alloy and making it a potential replacement for steel bodies of cars made using resistance spot welding.

Traditional arc welds and high energy density joining techniques are expensive in todays' cut throat competition era. Few under develop joining techniques like ultrasonic joining, electromagnetic joining and adhesives will still need to address present issues with long-term performance and productivity disadvantages. The current and potential focus area for welding of Al alloy thin sheet is mentioned in below Figure 6.

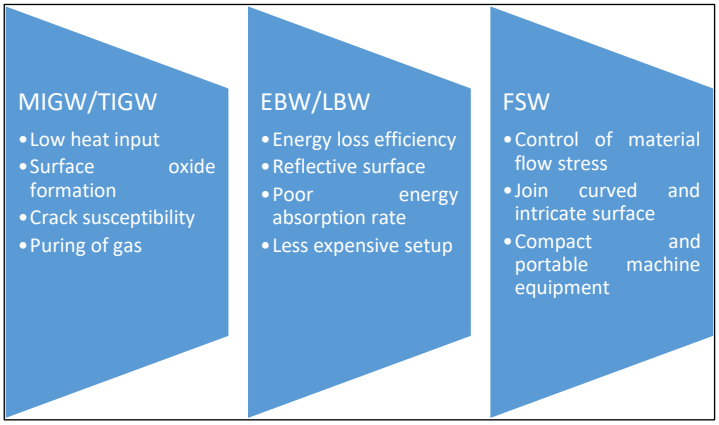

Figure 6: The current and potential focus area for welding methods.
Source: Authors, (2024).

It's equally important to consider further developments in fusion welding technology like cold wire feed LBW, high-brightness fiber lasers, and hybrid laser-arc-friction stir welding, which offer even greater control and efficiency for joining thin aluminum sheets, however its cost effectiveness for domestic low cost automobile need to be explored.

Automotive panels will keep use of Al alloys because of its lightweight and environment friendly. The coming decades will be a prosperous time for aluminium structures as they contribute to society's efforts to address the current and future environmental challenges. Cost remains a hurdle for wider aluminum adoption, as it's generally more expensive than steel. However, advancements in processing and recycling are bringing down costs, and the long-term fuel savings often outweigh the initial investment.

I anticipate that all researchers and technologists will work together in the future to tackle the world's ecological issues by using aluminum structures.

VI. AUTHOR'S CONTRIBUTION

Conceptualization: Sachindra Doshia, Vaghosi Ketan and N D Mehta.
Methodology: Sachindra Doshia, Vaghosi Ketan and N D Mehta.
Investigation: Sachindra Doshia, Vaghosi Ketan and N D Mehta.
Discussion of results: Sachindra Doshia, Vaghosi Ketan and N D Mehta.
Writing – Original Draft: Sachindra Doshia, Vaghosi Ketan and N D Mehta.
Writing – Review and Editing: Sachindra Doshia, Vaghosi Ketan and N D Mehta.
Supervision: Sachindra Doshia, Vaghosi Ketan and N D Mehta.
Approval of the final text: Sachindra Doshia, Vaghosi Ketan and N D Mehta.

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