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Journal of Technological Development

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Presentation of the Content

In the first chapter we present, *Sustainable development models strategies analysis in the dynamic railway industry linking technological transformation*, by GARCÍA-RODRÍGUEZ, Carlos Iván, CRUZ-GÓMEZ, Marco Antonio, TEUTLI-LEÓN, María Maura Margarita and MEJÍA-PÉREZ, José Alfredo, with ascription in the Benemérita Universidad Autónoma de Puebla, as a second article we present, *Integration of a malt kilning model and a solar air heater model for its use as a viability estimation tool*, by LANDA-RIVERA, Ismael, HERNÁNDEZ-RUÍZ, María de los Ángeles, PILATOWSKYFIGUEROA, Isaac and GARCÍA-GONZALEZ, Juan Manuel, with ascription in the Universidad Autónoma de Zacatecas, as the following article we present, *Low-cost conditioning amplifier based on operational amplifier array for Michelson interferometer*, by BERMUDEZ-MORALES, Valeria & ROJAS-RAMIREZ, Sergio Raul, with ascription in the Universidad Aeronáutica en Querétaro and Centro Nacional de Metrología, as the following article we present, *Virtual instrumentation on CAN network for process monitoring Red CAN de instrumentación virtual para monitoreo de procesos*, by SANCHEZ-QUINTAL, Ricardo Jesús, UC-RIOS, Carlos Eduardo, DURAN-LUGO, Juan Miguel and LUGO-DEL TORO, Julio Francisco, with ascription in the Universidad Autónoma de Campeche.

Content

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Sustainable development models strategies analysis in the dynamic railway industry linking technological transformation

Análisis de estrategias de modelos de desarrollo sustentable en la industria dinámica ferroviaria vinculando la transformación tecnológica

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Abstract

Currently there is a global need to generate a sustainable development model that optimizes the functioning of the dynamic railway industry and that can be updated along with technological transformations. The objective of this research was to analyze the strategies of sustainable development models in the dynamic railway industry, linking technological transformation to ensure its long-term operation. On the other hand, railway systems that operate with well-structured sustainable development models have ample possibilities of long-term persistence, however, railway systems that lack this are destined to fail before the economy that can generate subsidies detonates. The methodology was carried out by a mixed analysis for it, it was relevant the application of quantitative and qualitative methods of parameters of sustainable development in train systems based on control variables such as economic, social, environmental, equity, areas. Socio-economic-environmental, stability, viability and ecological. The technical data obtained from different sources of scientific information were the basis for decision-making that contributed to the formulation of a sustainable development model in railway systems. The characterization and optimization of the model will be the subject of future work.

Railway systems, Sustainable development, Subsidies

Resumen

En la actualidad existe la necesidad mundial de generar modelos de estudio de desarrollo sustentable que optimice el funcionamiento de la industria dinámica ferroviaria y que pueda actualizarse a la par de transformaciones tecnológicas. El objetivo de esta investigación fue analizar las estrategias de modelos de desarrollo sustentable en la industria dinámica ferroviaria vinculando la transformación tecnológica para asegurar su operación a largo plazo. por otro lado, los sistemas ferroviarios que operan con modelos de desarrollo sustentable bien estructurados tienen amplias posibilidades de persistencia a largo plazo, sin embargo, los sistemas ferroviarios que carecen de este están destinados al fracaso antes de que detone la economía que puede generarle los subsidios. La metodología fue llevada a cabo por un análisis mixto para ello, fue relevante la aplicación de métodos cuantitativos y cualitativos de parámetros del desarrollo sustentable en sistemas de trenes en función de las variables de control como económica, social, medioambiente, equidad, ámbitos socioeconómico ambiental, estabilidad, viabilidad y ecológica. Los datos técnicos obtenidos de diferentes fuentes de información científica fueron la base para la toma de decisiones que contribuyen a la formulación de un modelo de desarrollo sustentable en sistemas ferroviarios. La caracterización y optimización del modelo será motivo de trabajos futuros.

Sistemas ferroviarios, Desarrollo sustentable, Subsidios

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Introduction

The world demand for transport is growing logarithmically in the transfer of passengers and cargo, due to social and economic progress, however, this will generate a demand for energy and greater atmospheric polluting emissions in the next century. The railway has the potential to reduce this growth in urban environments. High-speed rail is an alternative to short-distance air travel, and freight rail can complement other modes of transportation by providing efficient mobility (Global Railway Review, 2022).

Transport annually consumes around 50% of world oil production with around 25% of the planet's polluting emissions. Therefore, the implementation of a railway transport in its different energy modalities in trajectories typical of this transport reduces the time of transfers and pollutants, making it an efficient means of transport. Currently, railway systems transport around 10% of passengers and merchandise globally with an energy demand of around 2% of world oil production.

Currently, 800 million people in the world are mobilized by rail-electric transport, while a couple of decades ago there were around 320 million people. The railway sector is the system that has the greatest affinity for electrification due to its infrastructure conditions and that will hardly be matched by the automotive, aeronautical, and maritime sectors in the coming decades. Passenger rail systems present 90% greater electrification than freight systems.

The regions with the greatest activity for high-speed electric trains are Europe, Japan, and Russia, while Latin America depends on hybrid systems or fossil fuels in low-speed rail systems of less than 250 km/h on short, medium, and long distances.

Conventional railways account for about 90% of global passenger movements, first India with 39%, China 27%, Japan 11%, and the European Union 9% (Sustainability – UIC - International union of railways, 2023).

Currently there is a global need to generate sustainable development study models that optimize the functioning of the dynamic railway industry and that can be updated along with technological transformations.

The objective of this research was to analyze the strategies of sustainable development models in the dynamic railway industry, linking technological transformation to ensure its long-term operation.

On the other hand, the railway systems that operate with well-structured sustainable development models have ample possibilities of long-term persistence, however, the railway systems that lack this. They are destined to fail before the economy that the subsidies can generate for them explodes.

Sustainable development

Sustainable development is an action that nations use to promote a global economic development model for environmental conservation with social equity.

This satisfies the needs of the present without compromising the ability of future generations to satisfy their own needs by putting it as a "political manifesto" citizens, civil organizations, companies, and governments to promote actions, ethical principles and new institutions oriented towards a common objective: sustainability.

The holistic vision of sustainable development has been challenged by a broader, complex vision where the quantitative is subsumed in the qualitative – which articulates care for the environment, as well as the integrity of ecosystems, solidarity-based social relations oriented towards equity and the institutional environments of politics for the exercise of governance. The priorities of sustainable development and efficient implementation of integrated policy decisions require institutional changes at different levels and involve all private and government sectors, see figure 1.

The 2030 Agenda comprises 17 Sustainable Development Goals structured into 169 goals, the description of which has as its central axis people, the planet, prosperity, collective participation, and peace with the purpose of ending poverty, fighting against inequality, injustice, and guarantee the protection of the environment and its natural resources.

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This is universal and transformative, an ambitious action plan to redirect the world towards a sustainable future, it takes up the Millennium Development Goals and is an opportunity to develop new procedures and intensify efforts that manage to influence the fulfillment of the goals and aspirations set forth by the international community (Cepal, 2019, SUSTAINABLE Development, 2018 and Zawadzki et al., 2022).

Figure 1 Venn diagram, sustainable development, Group of Tribology and Transportation Faculty of Engineering BUAP; 2023

Railway systems; A solution to urban mobility?

The growth in the railway networks for 2050 was estimated with an increase of 2.7 times with respect to the year 2023. Highlighting India and Southeast Asia which will have an increase of seven times, China three times, Japan 0.25 times and 0.45 times the European Union. Railway movements mobilize around 10% of the world population and two thirds of freight transport is carried out on electrified railways, it is expected to reach an electricity consumption of around 700 TWh.

The incorporation of a railway system to a densely populated area will generate capital gains in the value of real estate and land, capitalization of commercial areas, improve mobility and public policies will be implemented to ensure that these transformations provide subsidies to the railway industry. The implementation of regulations that regulate the collection of taxes for train subsidies could be implemented as charges to alternative means of transportation based on the pollutants they generate, charging for road congestion, and road pricing.

Air pollution and mitigating climate change are global concerns. A previous analysis shows that rail systems are 12 times more efficient in energy consumption and pollutant emissions compared to road and air travel in terms of “final energy per passenger transported” and eight times more efficient than trucks per “ton of cargo transported”. The efficiencies of the railway system are due to the reduction of the coefficients of friction in the rolling area in the metal-metal contact, which minimizes the torque required by the motor source, which decreases the energy consumption when dragging cargo with positive impacts. Economically and environmentally (Transforming our world: the 2030 Agenda for Sustainable Development | Department of Economic and Social Affairs, s. f.).

The railway transport modeling for the evaluation of sustainable performance through sustainability indices such as; environmental, energy consumption (green mode of transport), social, greenhouse gas emissions, noise pollution, poor management performance, performance evaluation, identification of indicators that hinder sustainable performance, policies, axes of government plans and programs, driving standards of sustainability, reduction of accidents, climate change, competitive logistics, inclusion of intermodal road-rail transport means, analytical hierarchy process findings, logic methods, specialized methodologies (fuzzy logic, fuzzy spherical environment, neural networks, data mining, quality, decision-making based on public policy priorities freight transport imposition of how to promote consumer preference expansion of transport with global trends), reasonable access to cargo facilities equitable ecological manner (supply chain) (Railway-News, 2023).

Sustainability must be included in the objectives of a transport company, however, in practice and in decision-making, sustainability is not seen as the main concern of transport companies, governance and policy development incentives and sanctions. This is a concern because non-quantifiable variables depend on people's point of view but affect decision making in higher percentages than those made through quantifiable analysis.

Dynamic sustainable development models with control variables

Proximity to railways, highways and feeder roads have an impact on the expansion of cultivated land, grassland and building land, protected areas, respectively, Future urban expansion is inevitable as predicted by global population growth models with influence on settlements in strategic areas of the planet. Large cities are the result of demographic growth in specific geographical areas with large concentrations, however, the expansion of these large cities creates scenarios of radial increase.

On the other hand, models of large cities have been carried out in some countries such as China, leading to the creation of model cities away from urban sprawl to disperse population concentrations, but the result is null. These model cities represent large initial investments, maintenance, mobility infrastructure, subsidies and incentives for people who wish to inhabit them. The result obtained for these model cities is a resounding failure and they represent ghost cities with a large infrastructure wasted until the radius of the urban sprawl absorbs them. (Ciulli & Kolk, 2023)

The modeling of urban expansion projects can serve as a reference for ecological environmental protection planning and sustainable development of land resources. These big changes in land use are bound to bring a series of ecological problems, such as climate change. Urban ecosystems have been seriously damaged, to analyze the dynamics in a scientific and rational way, it will be of great importance to optimize decision-making and execution of urban expansion projects that can largely ensure their sustainability. Model-based projects with a scientifically sound approach with iterations in optimizing possible solutions before execution greatly ensure the sustainability of the project.

However, when a project is executed without a strategic planning with scientific feasibility bases, it is destined to fail and in the early stages of the project it will face great limitations and complications with minimal possibilities of reaching project maturity and much less long-term sustainability.

The interrelation between the landscape and human activities help to analyze the relationship between these in an ecological environment.

In decision-making in the development of land use through geographic simulation models that consider; the spatial and temporal dynamics of land use, under the influence of natural and human activities subject to transitions of multiple factors that dynamically and iteratively evaluate improvements based on the model, identifying strategies for the analysis of patterns typical of the geographical region and conditioning factors of the system to simulate. Dynamic sustainable development models with control variables based on the growth of land use to avoid ecological impact as far as possible use more and more specialized methodologies carried out by experts in different disciplines who provide knowledge for the identification of variables of system control.

The methodologies used for modeling are computational model iteration techniques, information technologies, data mining, regional ecological assessments receptor risk assessment, spatial and temporal regional assessment, heterogeneity scale effects, quantitative and qualitative assessment, ecological risk in the fragmentation and diversity of the complex, analysis of the relationship between the landscape patterns (Guo et al., 2022).

Ecological spatial pattern in upward spiral problems in sustainable development

Rapid urbanization has vastly changed urban ecological spaces and the function of regional habitats, threatening regional ecological security and landscape sustainability expanding habitat quality is important for ecological security.

Integrated land use, natural, social and economic factors to monitor and assess the impact of urban sprawl on habitat quality urban sprawl and ecological soil have become more fragmented urban sprawl has changed from edge to edge sprawl peripheral type; The rate of urban expansion increased exponentially in ecological corridors ecological nodes that form an ecological spatial pattern of building patterns of ecological security (Xuto et al., 2022).

Urbanization is an essential driver that generates challenges such as global climate change and sustainable development, directly or indirectly affecting the change in urban landscape patterns, an expansion that has occupied a large number of agricultural and ecological spaces.

Resulting in more than 80% of the loss of natural habitat of local areas generating unbalanced and undeveloped urban ecological environmental areas driving global climate change, irrational human exploitation, ecologically based poverty, weak environmental capacity, water scarcity, and waste control by infrastructure non-existent in non-urbanized areas but that are triggered by the stimulation of distances being brought closer by the railway system, propitiating an ascending spiral of problems that relate the area to sustainable development.

In order to generate a project for a railway system with compliance with sustainable development, it must cover a very complete project with a 100-year growth and that the train service supply area is based on demographic growth, which, after all, will be the future customers and users of the train, so crossing a reserve with a railway system represents a project with minimal expansion growth if its purpose is its conservation, which is why this type of project puts ecological reserves at risk. The development of railway systems without a well-founded feasibility study that invade agricultural lands and areas of endemic flora in the region generate an impact of land use change with irreparable ecological damage.

The urban core of a region generates expansive growth according to demographic growth and, although exponentially and sometimes uncontrollably, they present a typified spatial pattern of growth; however, rapid urbanization due to the creation of railway systems in demographic areas that do not demand its utility due to its limited growth, it will generate an altered spatial pattern with invasion of regional habitats and represents a serious threat to habitats and biodiversity.

Research on the ecological impacts of urban expansion, according to research methods, can be classified into three categories: first, ecological quality assessment (documentation of biomes, flora, fauna, grassland, arable land, water areas, forest land, unused land, construction land, city limit, groundwater areas, underground rivers, lagoons, mangroves, archaeological zones, studies of events in different paleontological eras of events in the region, among others), second, systems evaluation (environmental quality index, ecological, demographic expansion) and the ecological index of remote sensing.

Third, the quantitative and qualitative analysis based on the ecological model (assessment models, including Integrated Ecosystem Valuation, services and compensation model, artificial model. The intelligence model for ecosystem services, social values model for ecosystem services, minimum cumulative resistance model among others, since the purpose of the ecological impact study must fully evaluate ecological safety, environmental impact analysis and prediction.

Regional habitat quality studies are limited by available land, so data collection in historical periods and in future scenarios. The scope of this study explores the current situation and spatiotemporal variations of habitat quality in urban areas, agglomerations, or individual cities.

The evaluation of the ecological impacts of urban expansion from the perspective of a pattern of ecological security of land use change. The global ecological and environmental problems that threaten the sustainable development of human society place as a priority the development of plans and programs to safeguard ecological security. This consists of three parts, first identification of the area of origin, second determination of resistance surfaces and third construction of ecological corridors.

This evaluation model develops direct identification and a comprehensive evaluation index system, core areas of nature reserves and scenic spots, indicator ecological sources, ecological sensitivity, landscape connectivity, habitat importance, morphological spatial pattern analysis method, model to overcome the deficiencies of the model, selection of areas of origin graph, theoretical method, theory of circuits to evaluate the structure of the ecological security pattern, areas of ecological origin that are most suitable for the status of species according to the headquarters necessary for generate current habitat quality, distribution map, natural, social and human influencing factors, identification and planning of ecological patterns the model main purposes explore spatio-temporal characteristics assess ecological security study area covering seven types of land use Land:

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Cropland, Forest, Grassland, Shrubland, Wetland, Water, Impervious Surface, and Bare Land Land-use data to explore spatiotemporal characteristics of land-use cover/change in natural habitat loss (Wei et al., 2022).

Ecological security pattern models and zoning of complex dynamic systems

Building models of ecological security and zoning patterns in complex dynamic systems greatly ensure the reduction of ecological risks in developments associated with rail transport infrastructure. Modeling diminishes major threats to biodiversity and ecosystem services, mitigating threats along rail infrastructure, by pre-assessing landscape ecological risk, regional resilience, ecological quality index, segmentation, and penetration of high-risk areas. risk and low-risk areas, highway expansion, identification and evaluation of risk areas, development of industrial parks, risks in urban areas, ecological corridors, connection with ecological sources, among others.

Mixed methods to integrate ecological risk assessment, promotion of infrastructure-driven ecological conservation planning and industrial parks. Influenced by the rapid development driven by transport infrastructure, evaluation of the magnitude of risk, infrastructure trends and industrial parks generating high risk such as; geological hazards, erosion by rain, expansion of human activities, amplification of risks under demands for anthropic intervention, design of corridors for the survival and migration of species with specific solutions aimed at each existing species in the area, design of monitoring the behavior of species migrations with impacts on genetic evolution and zoning optimization.

On a holistic scale, it was driven by type of land use and vegetation cover, while, on a local scale, low-risk areas were primarily shaped by landscape resilience ecological sources corridors, basically connecting most areas with good vegetation cover and important ecological functions this provides management tools adaptable to the synergies between development and mitigation of landscape risks (Bai & Weng, 2023).

Modeling of autonomous service agents; fixed routing or on demand

The potential of autonomous vehicle technology for a light rail station uses first and last mile services as mobility models. Event and agent simulation model Based on a matching algorithm, incoming passenger requests are prioritized and assigned to vehicles with capacity constraints. Urban sprawl has an impact on system performance, services become relatively better to meet urban sprawl, while fixed routing remains superior in most key performance indicators.

Urbanization and development have led to larger and denser cities, caused congestion, synchronously with the development in autonomous transportation technologies. The deployment of efficient feeder strategies will have an impact on the design of cities, quality transport services, equity perspective. First and Last Mile Feeder Services is a light rail model that accounts for demand in space-time, route and bus stop design, integration of capacity constraints, and routing algorithms in an agent-based simulation model. Queuing systems with data analysis.

The intricate logic of the model is described in a series of event-based graphs and pseudocode that describe event transitions demonstrating that fixed routing performs better than demand response scenarios when evaluated in a cost-effectiveness framework. The benefit, fixed routing is more robust and can handle variations, what makes it much more consistent is that the optimal route design is circular and synchronizes with the light rail frequency (Rich et al., 2023).

Plans and programs for sustainable development in train systems

The impact of urban light rail systems reduces congestion, travel time and pollution. An analysis of differences to a sample of cities that did not have rail systems in the initial year. The evidence determines that an increase in the supply of rail transport leads to less congestion, less travel time and pollution. The European Commission revealed that congestion due to road transport generates polluting emissions and are the main cause of deaths per year in the world (more than AIDS, malaria and flu combined).

Light rails offer great advantages in urban mobility such as, they operate on steep slopes, tight curves, travel speed, reliability and can carry up to three times more passenger capacity than a bus, however, light rails are more expensive than regular buses. One of the variants worth explaining is that light rail transport prices are much lower, which benefits social equity, but this is because the provision of subsidies makes prices competitive with other means of transport functioning as a means of regulating the economy with an impact on different sectors.

However, the cost of km traveled per unit is much higher, so how can you have competitive prices? This is because the subsidies contribute to lower the final price of mobility in the light rail system, and it is provided by the government for the different income such as taxes and rental of spaces of the railway infrastructure. (Liu et al., 2023)

The trains in their different classifications are intended for large cities with large demographics so that they generate an impact in reducing travel time, traffic and pollution that increase over time, previous studies indicate that cities with a new rail system have a 7 % less congestion, 1% less travel time and 3% less pollution than cities without a rail system (Fageda, 2021).

Train projects under these conditions may represent a partial solution to these problems, but their impact will be appreciated over the years with population growth, which is why sustainable development models are even planned for long terms (100 years).

It is worth mentioning that a railway system is a company which, due to its complexity in terms of factors such as initial investment, maintenance, modernization, and quality of the system, according to previous studies from different countries, does not represent a competitive company in prices to the user or a company that generates great economic profits.

The objective of a railway system is to contribute to the reduction of travel time, traffic and pollution, but it should not be forgotten that due to the complexity of the system and the variations in the subsidies of the different levels of government.

Over the years it can become inoperative due to the high costs that it requires and in many cases the railway infrastructure is abandoned due to the high operating costs and the infrastructure is plundered by the people of the region, becoming a source of contamination to the ecosystem and a project that to operate again will require large investments to recover the lost infrastructure and enable the system to make it operational. Another factor that must be considered is that the useful life of a train, although it depends on its extension due to due maintenance, like all machines, has a useful life limit and that the plans and programs of railway projects in the long term (100 years) take into consideration that the system will have to be replaced at least three times in the periods of technology renewal, in case of not doing so, serious accidents will occur that will take the lives of the users.

Methodology

This research has a mixed approach, applying both quantitative and qualitative technologies, using systematic processes, as well as recorded and estimated data. The aims of this research was to analyze the strategies of sustainable development models in the dynamic railway industry, linking technological transformation to ensure its long-term operation. The methodology was carried out by a mixed analysis, for this, it was relevant the application of quantitative and qualitative methods of parameters of sustainable development in train systems based on control variables such as economic, social, environmental, equity, socio-economic-environmental spheres, stability, viability, and ecology.

The technical data obtained from different sources of scientific information were the basis for decision making that contribute to the formulation of a model of sustainable development in railway systems. Sustainable development models proposed by different researchers and experts in the area of railway systems, belonging to different countries and international organizations that have exhaustive monitoring in the railway area, have developed iterative models of railway technological development with different scientific techniques, (they were documented through different means such as; technical reports from international organizations, case studies reported in international papers, cases documented by formal media, etc.).

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Conclusions

At present there is no complete model that can lay the foundations according to the regulation of variables of a model of sustainable development of railway systems, because this would be a complex model that covers several disciplines and decision-making with respect to the projects of railway systems in their different stages are regulated by qualitative analysis above the quantitative ones, depending on the appreciation and convenience of those responsible for the project in their different execution positions, which follow trends that suit their interests, making them fall more Number of errors that will affect the railway system in its different stages until its renewal or failure.

The models of railway systems are considered by discipline as isolated case studies and specialized computational techniques can be applied for their iteration, however, there are non-programmable criteria such as qualitative criteria that do not allow generating a model for that case study with accurate decisions since it depends on the person(s) making the decision. Most of the companies and governments, faced with this situation, overlook the majority of case studies that must support a railway project by venturing into construction and then adapting studies with decision-making based on their results in work and environment.

However the train does not forgive and the race in favor of subsidies, depreciation, maintenance, modernization of a project of this nature in conjunction with errors during the construction stages of the project will make the failure approach before the renewal of the system in one stage early with no possibility of reaching that triggered the sustainable development of the project.

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Integration of a malt kilning model and a solar air heater model for its use as a viability estimation tool

Integración de un modelo de secado de malta y de un calentador solar de aire para su uso como herramienta para estimar viabilidad

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Abstract

The current work deals with a model of malt kilning, coupled to the design equation of a solar air heater, to use it as a tool for the estimation of the energy saved through its operation. The kilning model was previously validated by previous works, while the design equation for the solar air heater was obtained by a published characterization of a solar air collector manufactured in Mexico, to use it as a platform to evaluate its behavior in the solar conditions with a known equation. The kilning model was obtained previously by other works, where the malt was characterized, and its drying parameters were obtained, this model was modified to improve its convergence. This coupled model will be used to do experiments on the thermal behavior of the process, being able to predict the behavior of the process and being capable of modifying the heating schemes and reflux fractions, and verifying if the solar heating of the process is viable.

Malt Kilning, Solar energy, Mathematical model

Resumen

El presente trabajo es un modelo del secado de malta, acoplado a las ecuaciones de diseño de un calentador solar de aire, para su posterior uso para la estimación de la energía ahorrada a través de su operación. El modelo de secado esta previamente validado por trabajos previos, mientras que las ecuaciones de diseño se obtuvieron de una caracterización de un colector solar fabricado en México, para utilizarlo como plataforma para poder conocer el comportamiento del modelo con una ecuación de diseño conocida. El modelo de secado se obtuvo de trabajos previos, en donde se caracterizó la malta y se obtuvieron sus parámetros de secado, el modelo se modificó para aumentar su convergencia. A partir de este modelo entonces se puede experimentar en el futuro con distintas configuraciones, en especial al variar la cantidad de colectores o los esquemas de reflujo o temperatura, para poder obtener un mejor uso de la energía en el proceso y, además, saber si el proceso en conjunto es viable.

Malta, Secado, Energía Solar, Modelo Matemático

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Introduction

The beer brewing industry in Mexico produces 2,615 kt of malt each year as feedstock [I], in order to achieve this production, fossil fuels are used to obtain energy, most of this energy is used during the kilning of green malt, where germinated barley is dried to achieve the optimal characteristics for its use and storage. To achieve a reduction in the use of fossil fuels, and hence, the reduction of emission of CO_2, it is possible to integrate solar thermal energy to the process.

Therefore, green malt kilning is central process in the brewery, and this process consumes between 1,058 KWh and 1,543 KWh per ton of malt, consuming about 900 to 1,200 KWh as thermal energy for heating air. As this process consumes a great amount of energy, it is possible to conduct strategies to reduce the burning of fuel. The process of malt kilning was modeled to know the behavior of a previously stablished temperature scheme, therefore enabling it to be coupled to the design equation of a solar collector and, through that coupling, being able to estimate the outlet temperature of the device and the energy difference between the outlet air temperature of the collector and the target temperature of the process, in this way solar energy contribution could be calculated via this difference.

Visual Basic for Applications was used to model the process, using Microsoft Office Excel 365 as a platform and data output. The model is based on the balances and proprieties previously derived and estimated from validated models, whilst the behavior of the solar collectors is based on the design curves obtained experimentally for flat plate solar air heaters, previously reported in studies of their performance.

Malt kilning model

Since 1974, the deep bed drying of grains has been studied [II]. The simulation of such process is based in the assumption that the water is evaporated from the surface of the grain, and the limiting factor is the formation and drying of a thin film of water on its surface [II]. This model was subsequently adjusted to malt and barley in 1984 [III] and has transcended until the most recent studies, where it has been improved by providing better experimental parameters [IV].

The last of this study adapts the kinetics and equilibrium to the matter and energy balances provided by Nellist and adapted by Bala and Woods [V].

Whilst for the evaluation of the equilibrium moisture me, the experimental data of different temperatures was fitted to the Guggenheim, Anderson, and Boer Isotherm to obtain temperature dependent coefficients.

For the moisture balance:

$$\Delta w_a = -\rho_m \cdot \frac{\Delta z}{G}\left(\frac{\Delta M}{\Delta t}\right) \tag{1}$$

M: Malt moisture (kg of water/ kg of dry matter).
Δz: Layer thickness (m).
ρ_m: Grain bed density.
Δw_a: air moisture change on the bed layer (kg of water/ kg of dry air).
Δt: Elapsed time (s).
G: mass flow (kg of air/s m^2).

For the moisture equilibrium on the bed layer:

$$M_{(t+\Delta_t)} = M_{(t)} \cdot e^{-k\cdot\Delta t} + M_e(1 - e^{-k\cdot\Delta t}) \tag{2}$$

$M_{(t+\Delta t)}$: Malt equilibrium moisture in the elapsed time (kg of water/ kg of dry matter).
$M_{(t)}$: Starting malt moisture (kg of water/ kg of dry matter).
M_e: Equilibrium moisture of the layer (kg of water/ kg of dry matter).
k: drying constant.

Where:

$$k = \frac{D_{ef}}{r^2} \qquad r = 5mm \tag{3}$$

$$D_{ef} = 0.41036 \cdot exp\left[-\frac{5108.4454}{(T_a + 273.15)}\right] \tag{4}$$

D_{ef}: Diffusion coefficient of water into air.
r: grain diameter.
T_a: Air temperature.

Whilst for the evaluation of the equilibrium moisture M_e, Lopez et al. (1997) [V] fitted the experimental data of different temperatures to the Guggenheim, Anderson, and Boer Isotherm to obtain temperature dependent coefficients [V]:

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$$M_e = \frac{AB \cdot C \cdot a_w}{(1 - C \cdot a_\omega)[1 + (B - 1) \cdot Ca_\omega]} \quad (5)$$

a_w: Water activity coefficient.

Where:

$$A = 0.01183 \cdot exp\left(\frac{464.017}{T}\right) \quad (6)$$

$$B = exp\left(\frac{943.854}{T}\right) \quad (7)$$

$$C = exp\left(-\frac{28.639}{T}\right) \quad (8)$$

T: Absolute temperature of air(K)

And for the energy balance:

$$\Delta T_a = \frac{\frac{\rho_m \cdot \Delta z}{G \cdot \Delta t} \cdot [\Delta M \cdot (C_v \cdot T_a + L_a - C_w \cdot T_m) - \Delta T_m \cdot (C_a + C_w \cdot (M + \Delta M))]}{C_a + C_v \cdot \left(w_a - \rho_m \cdot \frac{\Delta z}{G} \cdot \frac{\Delta M}{\Delta t}\right)} \quad (9)$$

C_v: Water steam heat capacity (kJ/kg°C)
C_w: Water heat capacity (kJ/kg °C)
C_a: Dry air heat capacity (kJ/kg°C)
w_a: Water content of air (kg of water/ kg of dry air)
L_a: latent heat of vaporization of water (kJ/kg)
ΔT_a: Air temperature chance in the grain layer (°C)

Whilst for the heat transfer balance:

$$\Delta T_m = \frac{A + \rho_m \cdot \frac{\Delta M}{\Delta t}\left[\frac{2 \cdot Y}{h_{ev}} + \frac{\Delta z}{G \cdot E} \cdot F\right]}{1 + \frac{\rho_m}{\Delta t} \cdot \left[\frac{2 \cdot B}{h_{ev}} + \frac{\Delta z}{G \cdot E} \cdot (B + C_w \cdot \Delta M)\right]} \quad (10)$$

ΔT_m: Malt layer temperature change (°C)
h_{ev}: Convective heat transfer coefficient of air.

Where:

$$A = 2 \cdot (T_a + T_m) \quad (11)$$

$$B = C_m + C_w \cdot M \quad (12)$$

$$E = C_a + C_v \cdot \left(w_a - \frac{\rho_m \cdot \Delta z}{G} \cdot \frac{\Delta M}{\Delta t}\right) \quad (13)$$

$$F = C_v \cdot T_a + L_a - C_w \cdot T_m \quad (14)$$

$$Y = L_m + C_v \cdot T_a - C_w \cdot T_m \quad (15)$$

C_m: Heat capacity of air (kJ/kg°C)
L_m: Latent heat of vaporization of water in malt (kJ)
T_m: Malt temperature (°C)

Solar air heating modeling

Solar air heaters are devices that take advantage of materials that absorb a great amount of solar light, to transform radiation to heat and transferring it to air passing through the device. The behavior can be predicted from equations of the type:

$$\eta = a_{01} - a_{11}X - b_{11}G_aX^2 \quad (16)$$

η: efficiency

Where: $X = \left(\frac{T_m - T_{am}}{G_a}\right)$ y $T_m = \left(\frac{T_e + T_s}{2}\right)$

These equations can be solved by a simple numerical method (Secant method) to obtain the outlet temperature based on the inlet temperature (T_e), the ambient temperature (T_a) and the Irradiance incident on the plane (G_a).

After that, the heat obtained from the heating of air is estimated and the difference between this heat and the objective heat is calculated.

To verify the model, the fitting of the efficiency curve reported by Perez-Espinoza et al (2020) [VI] for three collectors in series:

$$\eta = 0.6173 - 6.3567X - 0.0190GX^2 \quad (17)$$

A modifier of the incidence angle ($K_{\tau\alpha}$) was reported in the same study; therefore, it was used:

$$K_{\tau\alpha} = 1 - 0.1245\left(\frac{1}{\cos\theta} - 1\right) \quad (18)$$

θ: Solar radiation incidence angle.

Therefore, efficiency equation becomes:

$$\eta = 0.6173\, K_{\tau\alpha} - 6.3567X - 0.0190GX^2 \quad (19)$$

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Methods

The model was coded as an Excel VBA Macro, starting with the calculation of properties of the inlet air, then the outlet moisture, energy and temperature of the air in the collector was calculated, and also the heat needed to achieve the energy required to raise the air temperature to the desired objective temperature was obtained, after that, the drying process begins, after its completion, the data obtained for each layer of the grain bed and the properties of the air and malt are written in the Excel sheet who serves as data log for the process.

The process takes place in this order (Figure 1), firstly the metrological, solarimetric and malt data are read from the excel data, then, in the point number 1 of the flow chart (Figure 2), the data enters a loop where the processes taking place in the collector are solved.

After doing this, the energy needed for reaching the desired temperature is calculated and the properties of such state are estimated. From this point on, matter and energy balance of each layer of the grain are solved. In this balances, all the equilibrium properties are calculated (malt moisture Me, air- water diffusion constant k), after that the balances are solved, In this point, the process continues with the wetting process, which is signaled on the diagram by the number 2 (Figure 3), this wetting process is put in place to avoid the oversaturation of the air over moisture levels greater than 98%, changing as an objective the difference of moisture of the malt; the process takes place for a n number of layers until the grain bed depth is reached

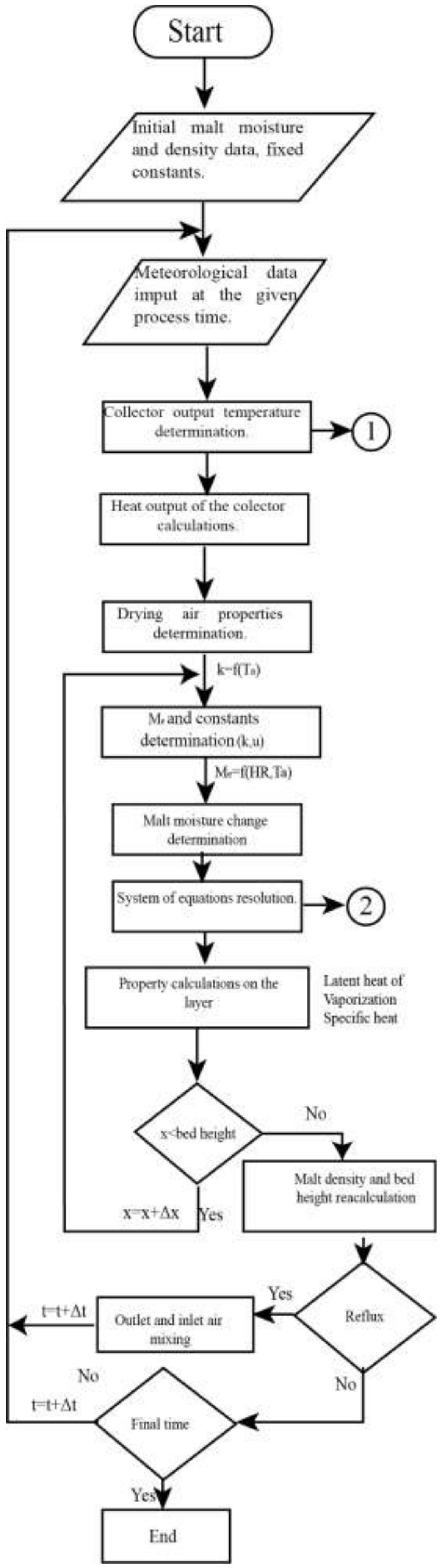

Figure 1 Process Flow chart

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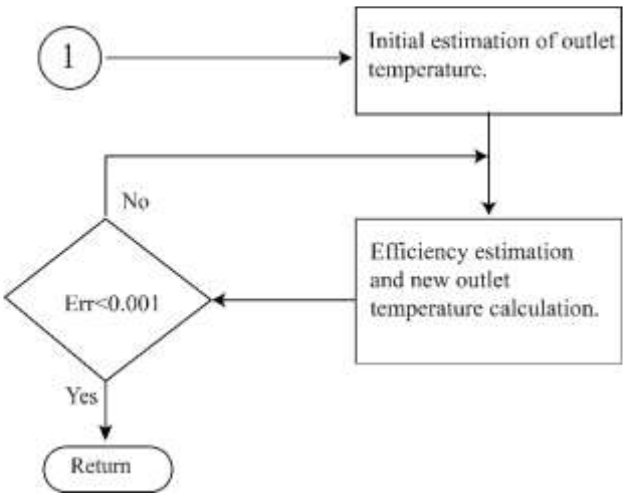


Figure 2 Solar Collector outlet temperature estimation

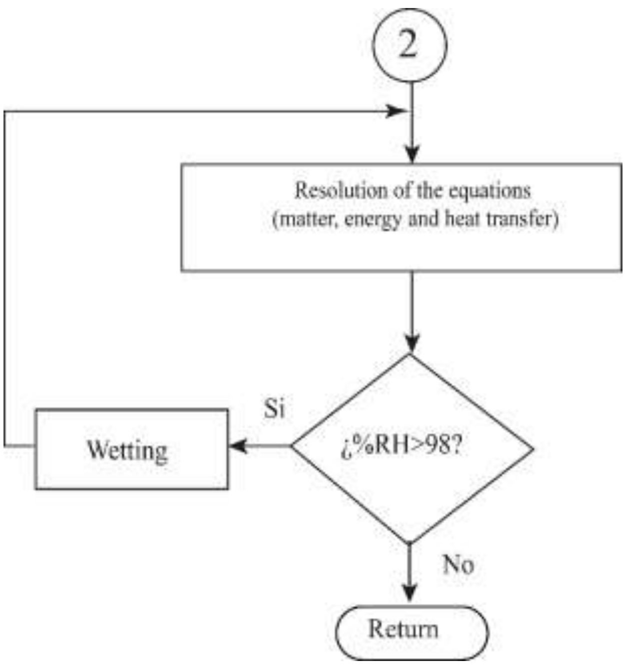


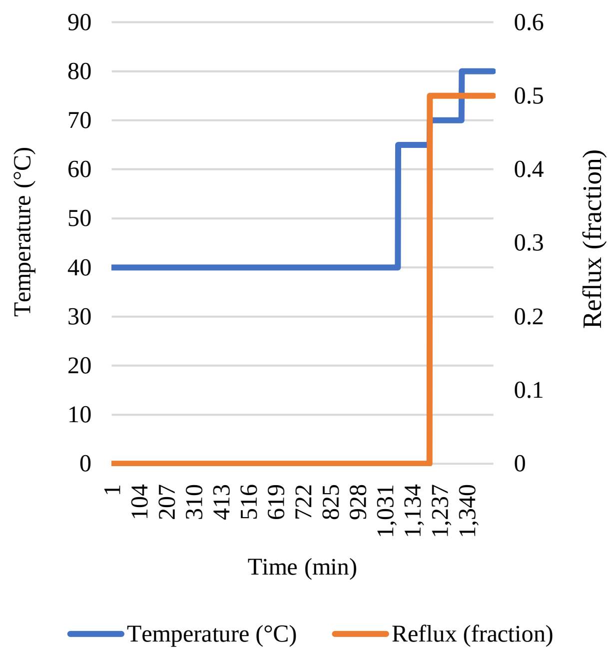
Figura 3 Ciclo de resolución del sistema de ecuaciones, con etapa de mojado

The solar energy cycle was solved using the secant method, mostly because it uses multiple parameters dependent on the outlet temperature.

The wetting cycle was solved using a LaGrange polynomial to interpolate towards a relative humidity of 98%, replacing the use of the Aitken-Neville search algorithm used by López et al. (1997) & Nellist (1974) [II & V].

Results

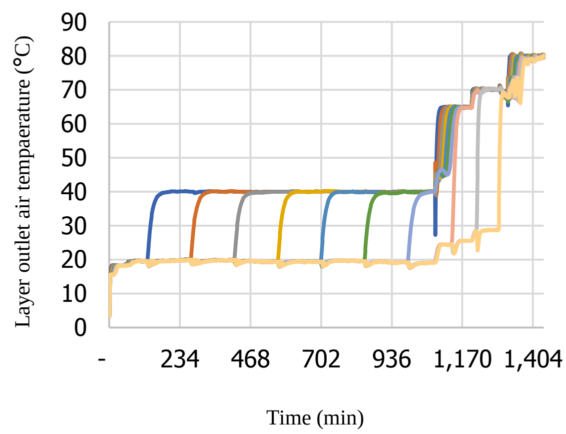
To test the system, a previously known and characterized scheme was used (Graph 1), this scheme includes a reflux of 0.5 at objective temperatures higher than 70° C [V].



Graph 1 Drying scheme used to carry out the simulation.

Drying model

The drying model was done in Excel® through a VBA macro, meteorological data was ordered from the first minute of the day, and missing data points where extrapolated, the temperature on each layer of the bed behaved as reported by López et al (1997) [V] and is shown in graph 2:



Graph 2 Behavior of the outlet temperature for each layer on the bed, from n=1 to n=10

The consistently, the behavior of the outlet temperature it's consistent with the behavior of the moisture leaving each layer and its evolution through time (Graph 3).

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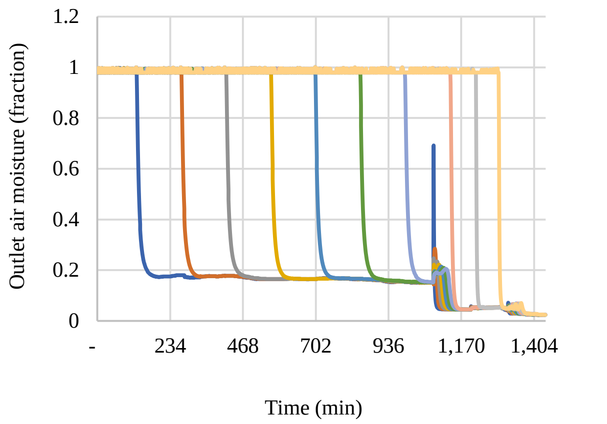
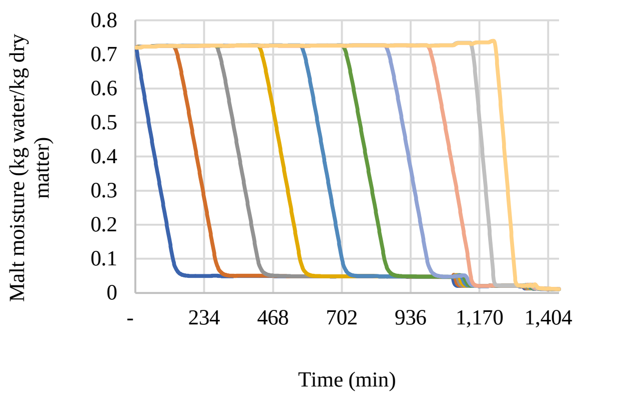


Graph 3 Evolution of the relative humility at the outlet of each layer of the bed

Also, the moisture content of the malt, behaves in a similar manner consistent with the change on the equilibrium (Graph)

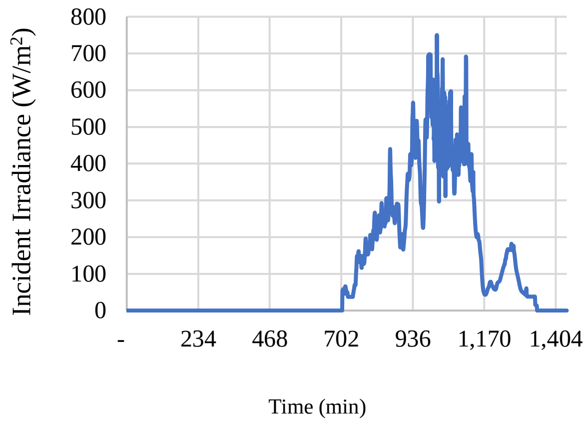


Graph 4 Evolution of malt moisture in each layer

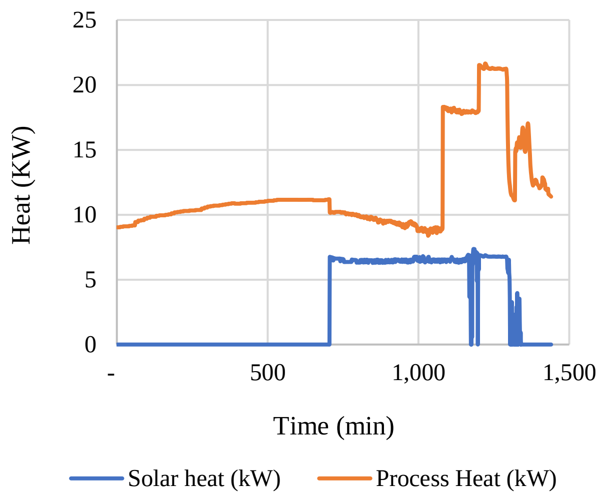
Solar heating model

Plane incident radiation was calculated by the model of Hottel y Woerts [VII y VIII] for clear sky radiation (with an inclination of 46° over the horizontal plane) this incident of radiation is shown on Graph 5.

The solar heating model was able to predict that for a day wait particularly low radiation (not greater than 800 W/m^2) The estimated energy saving amount to 22%. This behavior it's shown on Graph 6 together with the required heat.

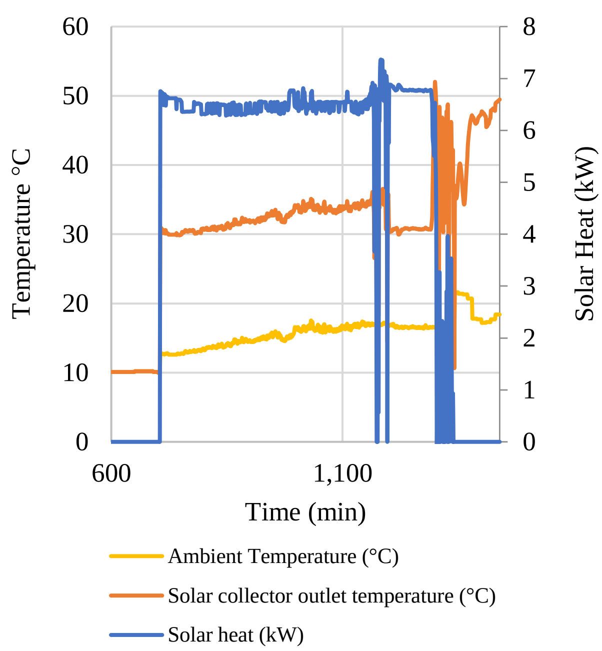


Graph 5 Irradiance incident on the collector.



Graph 6 Process heat

Also, the outlet temperature of the collector it's consistent with the thermal energy output from the collector and the fluctuations of ambient temperature (Graph 7).



Graph 7 Inlet temperature, output heat and ambient temperature

Financing

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Conclusion

The behavior of the drying model is consistent with previously reported models, having variation in the drying rate, which can be attributed to the diminishing atmospheric pressure in the place were data was gathered, Zacatecas, Zacatecas, Mexico.

The model described in this work for the solar collectors tends to fail when the reflux temperatures start to increase but, this can be attributed to the limitations of the design equations of the solar collector, since it only can predict the behavior at days with a continuous incident radiation because the model omits response time of the collector.

As subsequent work, the application of the model is postponed until the data of a month is processed so viability can be properly estimated.

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Low-cost conditioning amplifier based on operational amplifier array for Michelson interferometer

Amplificador-acondicionador de bajo costo basado en arreglo de amplificadores operacionales para interferómetro Michelson

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Abstract

A low-cost conditioning amplifier was designed and assembled with four operational amplifiers LM741. The objective of the design was the adequate amplification of electrical signals and with a design that allows the replacement of components if necessary. The performance of the conditioning amplifier was tested with the diode output signal of a Michelson interferometer, achieving an amplification ratio of 1:10 and the removal of DC voltage.

Amplification, Operational amplifier, Conditioning amplifier, Electrical signal conditioning

Resumen

Se diseñó y elaboró un amplificador-acondicionador de bajo costo con un arreglo de cuatro amplificadores operacionales LM741. El objetivo del diseño fue la adecuada amplificación de señales eléctricas con un diseño que permita el reemplazo de componentes del circuito en caso de ser necesario. El amplificador acondicionador se probó con la señal de salida del diodo de un interferómetro Michelson, obteniendo una adecuada razón de amplificación de 1:10 y la remoción de la tensión en CD.

Amplificación, Amplificador operacional, Amplificador acondicionador, Acondicionamiento de señal eléctrica

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1. Introduction

Interferometry techniques for the measurement of dynamic quantities requires to condition and amplify electrical signals of photodiodes, which transduce the received light beams into an electrical signal proportional to the optical power directed to its active area.

In a Michelson interferometer, silicon photodiodes are used. These diodes generate low-power electrical signals, so a conditioning amplifier is used to remove the DC voltage and to improve the performance of the signal acquisition systems (Hohenstein et al., 2013).

A conditioning amplifier is a device that is connected to the output of a device that generates an electrical signal (commonly a transducer) with the objective of altering this signal before it enters the data acquisition system.

A usual application for conditioning amplifiers is to amplify a signal at a specific ratio, being 1:10 and 1:100 common amplification ratios. In the present work, a conditioning amplifier was design to remove the DC voltage and amplify the diode output of a Michelson interferometer in a 1:10 ratio.

An operational amplifier is a voltage amplifier with extremely high gain. The operational amplifier LM741 has a typical gain of 200 V/mV (Franco, 2002).

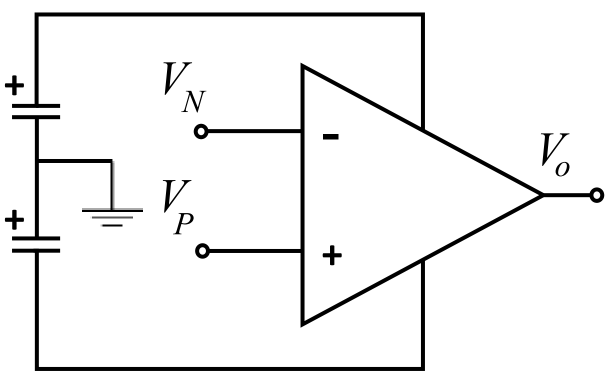

Figure 1 Symbolic representation of an operational amplifier. Made with PowerPoint.

Figure 1 shows the symbolic representation of the operational amplifier. The inputs identified with the symbols "-" and "+" in figure 1 are the *inverting* and *non-inverting* input, respectively. The voltages at these inputs are V_N and V_P. The *differential input voltage* is defined by the difference:

$$V_D = V_P - V_N \tag{1}$$

where:

V_D: Differential input voltage
V_P: Voltage at the non-inverting input
V_N: Voltage at the inverting input

Therefore,

$$V_O = A\, V_D = A(V_P - V_N) \tag{2}$$

where A is the gain and V_O the voltage at the output.

Depending on the way additional components are connected to the operational amplifier's terminals, the circuits can condition the input signal in diverse ways. The circuit configurations used in the conditioning amplifier presented in this work are the noninverting amplifier, the voltage follower, and the summing amplifier.

2. Basics

Non-inverting amplifier

To obtain a non-inverting amplifier circuit, the input signal must be connected to the noninverting terminal of the operational amplifier, as shown in figure 2. A non-inverting amplifier circuit has a positive gain value.

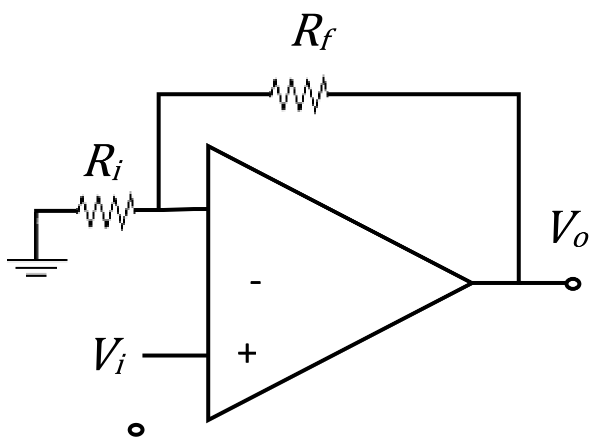

Figure 2 Schematic representation of a noninverting amplifier circuit. Made with PowerPoint.

In this configuration, the output voltage is given by:

$$V_O = V_i\left(1 + \frac{R_f}{R_i}\right) \tag{3}$$

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where:

V_o: Output voltage
V_i: Input voltage
R_f: Resistance in the negative feedback
R_i: Resistance between the inverting terminal an earth

As the gain is positive, the polarity of the output voltage will be the same as that of the input voltage (Coughlin & Driscoll, 1998).

Voltage follower amplifier

Letting $R_i = \infty$ and $R_f = 0$ in the non-inverting amplifier array (as is the case in figure 3) makes it a unit gain amplifier or voltage follower (Franco, 2002).

The application of a voltage follower lies in acting as an impedance transformer, from its input an open circuit its observed, while from its output a short circuit to a source of value $V_o = V_i$ is observed.

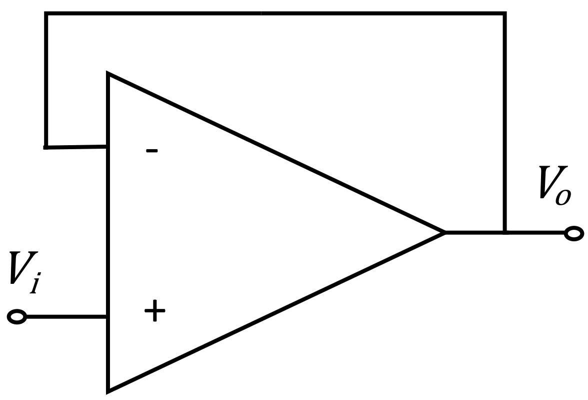

Figure 3 Schematic representation of a voltage follower. Made with PowerPoint.

The operational amplifier in voltage follower configuration does not amplify the input signal in any way; the output signal follows the input voltage directly. Its specialty, however, is to act as a resistance transformer, since looking into its input we see an open circuit, but looking into its output we see a short circuit to a source of value $V_O = V_i$ (Franco, 2002).

As the operational amplifier has remarkably high impedance, it demands little current. For this reason, the operational amplifier as a voltage follower acts as isolation dampers, nullifying the charge effects. The role of the follower is thus to function as a buffer between source and load (Franco, 2002). This makes it a useful circuit of first stage.

Non-inverting summing amplifier

The summing amplifier has two or more inputs and one output. In this configuration, the amplifier circuit delivers a voltage equal to the sum of the voltages at its input terminals.

Particularly in a non-inverting summing amplifier circuit, the input voltage will be connected to the noninverting input terminal of the operational amplifier, and the inverting input terminal will have an array of resistances in feedback with the output terminal and earth, as shown in figure 4.

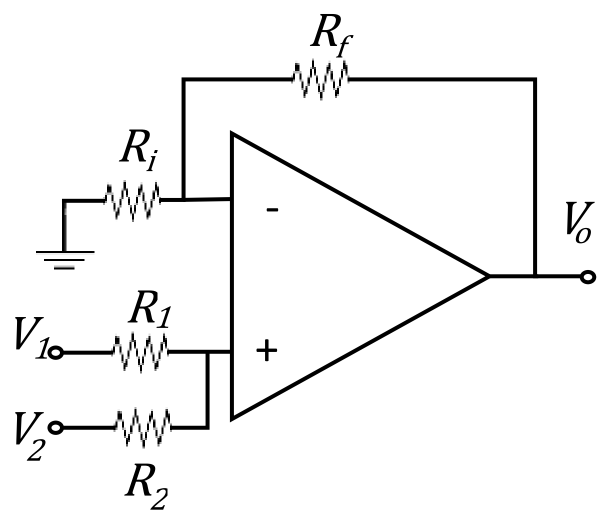

Figure 4 Schematic representation of a summing amplifier circuit. Made with PowerPoint

In this configuration, with an array with two inputs, the output voltage is given by:

$$V_O = \frac{(R_i + R_f)(V_1 R_2 + V_2 R_1)}{R_i (R_1 + R_2)} \quad (4)$$

where:
V_1: Input voltage 1
V_2: Input voltage 2
R_1: Input resistance 1
R_2: Input resistance 2

3. Methodology

Design of the conditioning amplifier

A conditioning amplifier circuit was designed and assembled with the goal of removing the DC voltage and amplify ten times the input signal.

Figure 5 shows the diagram of the design conditioning amplifier circuit, which has four LM741 operational amplifiers in different modes of operation. The photodetector used is a BPW34 of Vishay, and its output signal is the signal to condition and amplify (V_i).

The first stage of the circuit is an operational amplifier in follower configuration (follower), with V_i as its input voltage. Therefore,

$$V_{o,f} = V_i \tag{5}$$

In parallel, a second operational amplifier in follower configuration (conditioner) has at its input a potentiometer which supplies the voltage offset.

The outputs of the conditioner and follower stages are connected in parallel to the input of a third operational amplifier that is connected in a noninverting summing configuration (summing).

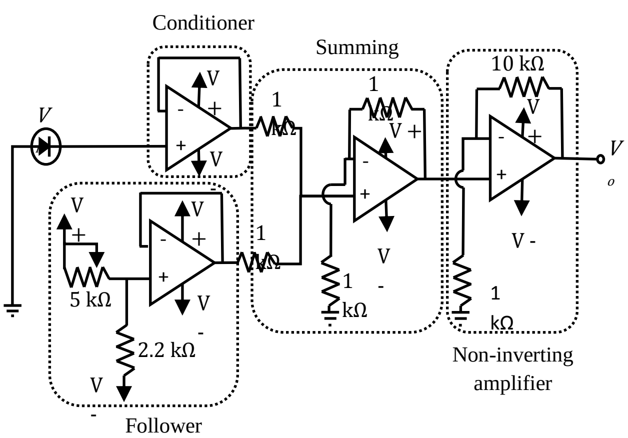

Figure 5 Schematic representation of the conditioning amplifier circuit with its four stages. Made with PowerPoint

From equation (4), the output voltage of summing amplifier in figure 5 is:

$$V_{o,s} = V_{o,c} + V_{o,f} \tag{6}$$

where:
$V_{o,s}$: Output voltage of the summing amplifier
$V_{o,c}$: Output voltage of the conditioner

In this case, $V_{o,f} = 0$, so the output of the summing amplifier is equal to the output of the conditioner:

$$V_{o,s} = V_{o,c} = V_i \;, \tag{7}$$

This voltage $V_{o,s}$ enters then to the last stage of the circuit, which consists in an operational amplifier in noninverting amplifier configuration (amplifier). From equation (2) and (7), the voltage at the output of this amplifier is:

$$V_{O,a} = V_{O,s}\left(1 + \frac{10\,k\Omega}{1\,k\Omega}\right) = 11V_i \tag{7}$$

This means that, in ideal conditions, the signal that enters the conditioning amplifier circuit is expected to be amplified in a ratio of 1:11.

Implementation

The circuit was assembled on four universal perforated circuit boards CL-005 (figure 6). On each circuit board a stage of the conditioning amplifier was assembled in accordance with the diagram presented in figure 5.

In addition to the components shown in this design, capacitors were used as filters of the voltage supply.

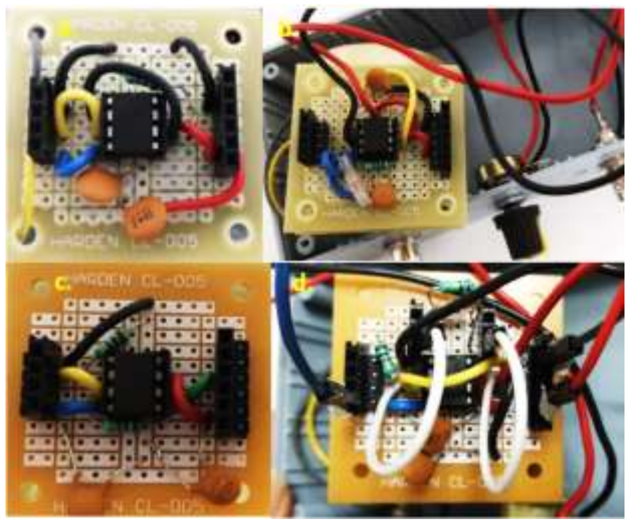

Figure 6 Stages of the assembled circuit: a) Conditioner b) Follower c) Summing amplifier and d) Non-inverting amplifier

Pin connectors were added on the circuit boards so that these could be connected one on top of the other as shown in figure 7.

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Figure 7 Conditioning amplifier circuit.

The real values of the resistances used in the non-inverting amplifying stage were measured with a multimeter before the circuit was stored in the case.

The cables for the input and output of the circuit were connected to the BNC connector previously embedded in the case for this purpose.

To generate the target signal to test the designed circuit, a conventional Michelson interferometer was used (Rojas-Ramirez & Pavon-Aguirre, 2013). This Michelson interferometer is used to measure mechanical vibration at UNAQ laboratories.

Ten direct measurements were made of the peak-peak value of the signal given by the interferometer. Subsequently, through a BNC cable the photodetector's output was connected to the input of the conditioning amplifier assembled. Ten measurements were made of the peak-peak value of the signal at the output of the conditioning amplifier's circuit.

4. Results

Table 1 shows the values of the resistances used in the amplifying stage of the conditioning amplifier circuit.

Resistance	Value [Ω]
R_f	9.88
R_i	0.99

Table 1 Real resistance values of the amplifying stage

Then, from equation (3), the expected relation between the circuit's input and output is given as $V_o = 10.98\ V_i$.

Table 2 shows ten voltage measurements at the input and output of the conditioning amplifier circuit.

Measurement	Input voltage [mV]	Output voltage [mV]
1	80.2	788
2	81.3	797
3	79.9	790
4	80.6	795
5	81.0	786
6	80.7	796
7	80.5	791
8	80.4	794
9	80.3	791
10	81.6	792

Table 2 Measurements read from oscilloscope of the peak-peak value of the interferometer's signal at the input and output of the conditioning amplifier

From the input measurements, an average peak-peak voltage of 80.6 mV was obtained, while from the measurements taken at the output of the conditioning amplifier an average peak-peak voltage of 792 was obtained. These measurements give an average gain of 9.82 attributed to the conditioning amplifier.

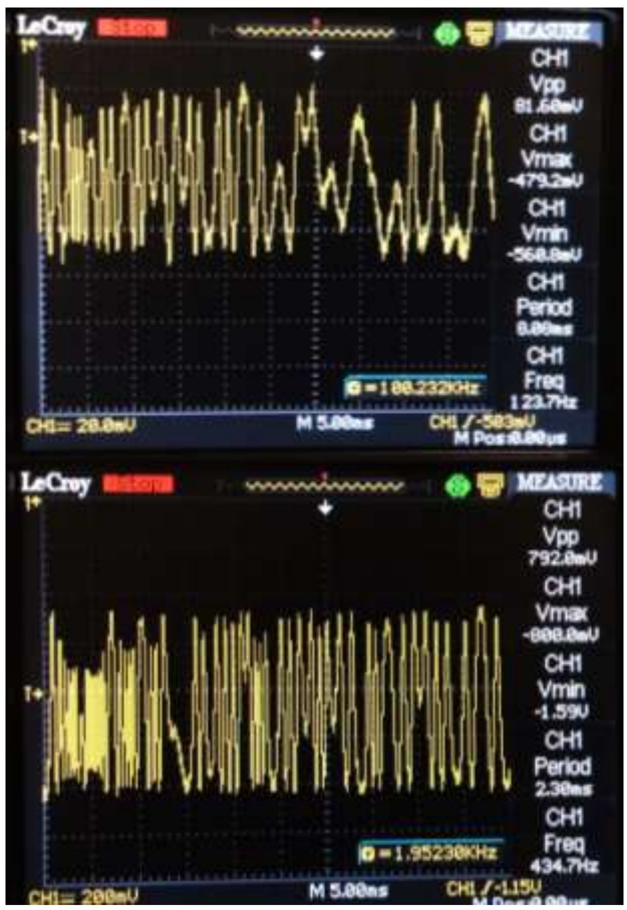

Figure 8 Original not treated signal (upper) and treated signal (lower) of the Michelson interferometer

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5. Conclusions

The assembled conditioning amplifier was a low-cost device with an amplification of 9.82, which is close to the expected gain of 10. This 2% difference may be reduced by changing the feedback resistance in the amplification stage of the circuit.

It is important to note that the conditioning amplifier presented in this work was designed to be used with a conventional Michelson interferometer, which has a single output signal.

6. Acknowledgments

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Virtual instrumentation on CAN network for process monitoring Red CAN de instrumentación virtual para monitoreo de procesos

Instrumentación virtual en red CAN para monitoreo de procesos Red CAN de instrumentación virtual para monitoreo de procesos

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Abstract

Virtual instrumentation has experienced significant advancements in recent decades, providing efficient and reliable solutions for the connection and communication of electronic devices in various applications. This article explores the most relevant developments in the field, focusing on the integration of Controller Area Network (CAN) networks and microcontrollers in distributed sensor projects. The article also presents a case study in which a CAN network is implemented along with the ESP-Wroom32 microcontroller in a distributed sensor project for alcoholic beverage production. The sensors used in each stage of the process, such as ultrasonic, load, water level, and motion sensors, are described, highlighting the importance of redundancy in monitoring critical parameters to ensure safety and proper process operation.

CAN, Virtual Instrumentation, LabView, Esp- Wroom

Resumen

La instrumentación virtual ha experimentado avances significativos en las últimas décadas, proporcionando soluciones eficientes y confiables para la conexión y comunicación de dispositivos electrónicos en diversas aplicaciones. Este artículo explora los desarrollos más relevantes en el campo, centrándose en la integración de redes de Área de Controlador (CAN) y microcontroladores en proyectos de sensores distribuidos. El artículo también presenta un estudio de caso en el que se implementa una red CAN junto con el microcontrolador ESP-Wroom32 en un proyecto de sensores distribuidos para la producción de bebidas alcohólicas. Se describen los sensores utilizados en cada etapa del proceso, como sensores ultrasónicos, de carga, de nivel de agua y de movimiento, destacando la importancia de la redundancia en la monitorización de parámetros críticos para garantizar la seguridad y el correcto funcionamiento del proceso. Se obtiene la manera adecuada de organizar los datos obtenidos en los sensores, la transmisión de estos paquetes de datos y los criterios lógicos para activar los actuadores del proceso.

CAN, Instrumentación Virtual, LabView Abstract

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Introduction

The term virtual instrumentation can be coined from the development of the general purpose interface bus (GPIB) in 1970 by the Hewlett-Packard company, which allowed, through serial communication, to connect electrical devices and measurement equipment; over time it became a worldwide standard, widely used in the electronics and measurement industry. It is estimated that in 2009 there were as many as 10,000 different types of instruments ranging from low-cost voltmeters to high-performance network analysers (Jia, 2009).

The GPIB is a network with the ability to connect up to 15 electronic devices through a 24-wire cable, the system has a main controller in charge of coordinating the communication between the different devices, it also stands out for its communication speed that ranges between 1.5 and 2 megabytes per second.

Nowadays, the diversification of instrumentation and control systems presents us with various options for integrating electronic devices, one of these options is the CAN network (Controller Area Network). CAN (Controller Area Network) contains a specific high-level communication protocol that was developed by BOSCH in the 1980s for use in the automotive industry (Ishak, 2019), but has been adopted in numerous applications outside this industry; it has also been used in virtual instrumentation and real-time control systems.

The use of CAN in virtual instrumentation allows the transmission of information between sensors and actuators in an efficient and reliable manner (Gharavi, 2020), resulting in increased accuracy and speed in data acquisition. It is a high-speed serial network that has been shown to be cost-effective, efficient and very economical. In a very simple way, sensors and actuators can be connected using a twisted pair cable that can reach speeds of 1 MBit/sec with 40 devices simultaneously (H. F. Othman, April 2006).

Hardware used

Embedded systems design is based on the programming of microprocessors and real-time operating systems. To integrate this knowledge into the project, the ESP-Wroom32 microcontrollers with node function in the network were used.

This microcontroller consists of a CPU (microprocessor) and two wireless communication modules WIFI and Bluetooth. The microprocessor has two processing cores with a processing speed of 240 MHz, which allows it to include real-time operating systems (Technical documents: Espressif Systems, 2023). The processor peripherals facilitate connection to a variety of external interfaces such as:

- SPI
- I2C
- Ethernet
- SD cards
- Touch interfaces

The module contains 4 MB of flash memory and only 38 pins (so as not to increase the size of the module), as shown in Figure 1. This device has become so popular due to its low cost and the possibility of being programmed by a variety of IDE interfaces such as the Arduino.

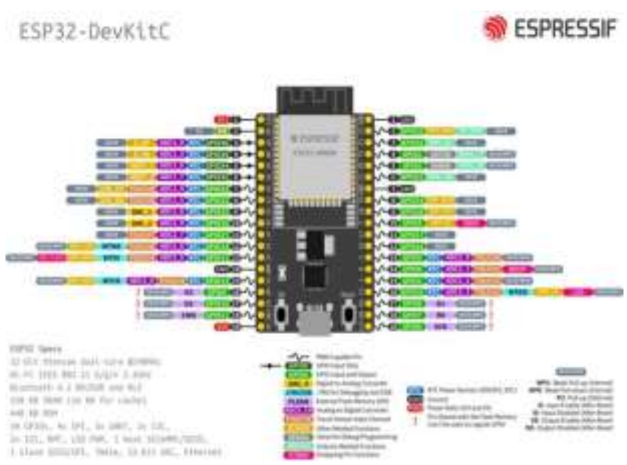

Figure 1 ESP Wroom32 (ESP32-DevKitC V4 Getting Started Guide, 2023)

Another device used in this project is the mcp2512 CAN controller, which is capable of transmitting and receiving remote source data strings, has reception masks and 6 different filters that are used to reject irrelevant messages, relieving the microprocessor of the computational burden messages, relieving the microprocessor of computational load. This device is connected and configured via the SPI interface.

The logic control includes interrupt pins that are provided to increase the flexibility of the system. It has a general purpose interrupt pin which can be configured to detect received messages, invalid messages, valid message, etc.

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The use of this pin is optional, as is the use of the status register, these pins are configured by the SPI interface (Microchip, 2018). The connection of the mcp2515 to the ESP Wroom32 microcontroller is done according to the diagram shown in Figure 2.

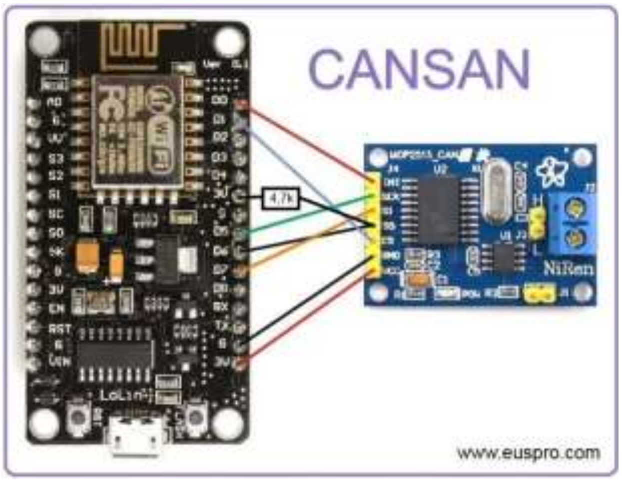

Figure 2 Connection of the mcp2515 (Arduino, 2023)

For the joint operation of the Wroom32 microcontroller and the Mcp2515 CAN controller, the library published by Cory J. Fowler (Fowler, 2023) is used, thus establishing the sending of data packets from the distributed sensors to the HMI interface via the CAN instrumentation network.

Digital sensors

There are different ways to obtain I/O data from a sensor, a common device for this is to use a stand-alone node such as the MCP25050 (Esro, 2009), however, for cases where processing of the acquired signals is required, it is necessary to use a microcontroller capable of performing the interaction with the specific sensor.

An example of the above is the case of ultrasonic sensors, where the duration of an input pulse is measured, the duration of an input pulse, and this cannot be done by the MCP25050 stand-alone node, which, although they are CAN nodes with input/output pins, analogue-digital converters, are not capable of processing signals as the microcontroller does.

The sensors implemented in this project are:

– HC-SR04 Short range ultrasonic sensor (Morgan, 2014).

– HX711 Sensor specialised in reading and processing load cells (Al-Mutlaq, 2023).

– HW-038 Water level sensor (Ashari, 2022).

– HCSR501 Infrared Motion Sensor (Wahyuni, 2021)

Most of the libraries for these sensors are directly available in the Arduino IDE application or on the network, this allows for quick implementation of all CAN network elements.

Methodology

For the implementation of this project it is proposed to use a CAN network, a graphical HMI interface developed in LabView and a CPU that will display the graphical interface board. In order to be able to measure different physical variables, different digital sensors connected to the esp-wroom32 microcontroller will be used. These microcontrollers are networked using the Mcp2515 CAN controller.

For the application of this network in a real case, the final stage of the production process in a distillery is selected (Figure 3). This stage can be subdivided into three main parts:

1. Last Distillation
2. Hydration and resting
3. Bottling and labelling.

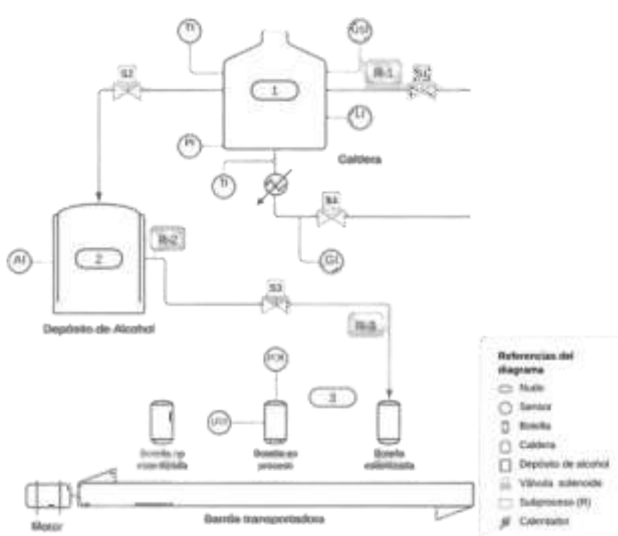

Figure 3 Proposed process

Final Distillation

Due to the fact that the value chain of the production of alcoholic beverages can have more than one distillation process, in this stage a hot infusion is carried out by distillation, with a very slow heating following a traditional One-Shot process in the London Dry, each distillation is carried out in 12 hours, extracting all the essence and achieving the desired aroma and flavour.

This is a critical stage due to the risk it represents and determines the quality of the product, for these reasons it was decided to implement redundancy in the measurement of the liquid level, i.e., it is ensured by three sensors the proper level before sending the command to ignite the boiler. In addition, after sending the ignition command, it is necessary to verify that the boiler is actually ignited the boiler has actually been ignited.

To check for proper liquid level, the information provided by the ultrasonic level sensor (USI), the load cell (PI) at the base of the tank and the level sensor (LI) is taken into account, thus reducing the likelihood of a high-risk event such as ignition without the proper volume of liquid.

A temperature rise by the TI sensor in the boiler chamber as well as the absence of gas provided by the GI sensor must be met to check ignition.

Hydration and standing

Once the liquid has been distilled, it is left to settle before hydration and once hydrated, it is left to settle again before bottling. The alcohol sensor (AI) is installed in this section to verify that there are no leaks in the hydration tank.

Bottling and labelling

In the last stage of the process, the bottles are disinfected with UV light. An ultraviolet radiation sensor (UVI) is used to verify that the UV light is switched on, which must detect a constant level of UV light and thus guarantee the disinfection process.

Additionally, a proximity sensor (PIR) is used to check the position of the bottles in the packaging and to avoid collisions.

Network implementation

The CAN network is a bidirectional network, which in this project was configured so that the nodes only send the information from the sensors to the central node (Node C), given the robustness of the CAN network it is possible to use the central node to send control signals to the actuators in the network, these control signals can depend on the decisions programmed in each node or be directly controlled by the CPU.

The capabilities of the CAN network allow:

1. To know the status of each node, if it is operational or presents an error.

2. The readings of the sensors and the operation of the actuators connected

3. To verify the data traffic on the network, loss of information packets; among others. Although in this network each node has only one sensor, it is possible to connect more than one sensor to each node.

The block structure of the network is shown in Figure 4.

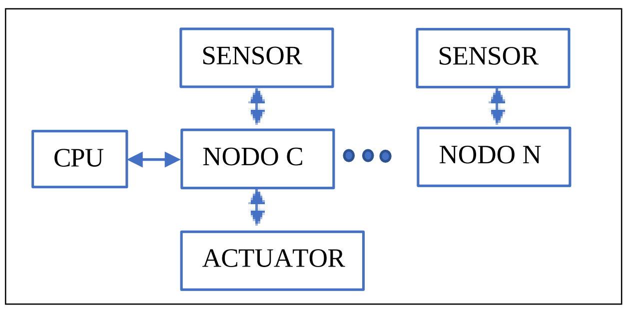

Figure 4 Communication schem

When implementing this network, we found 3 key points for the good performance of the CAN network in this virtual instrumentation application in the distillery. The first is to organise the information received from the sensors to the central node in an efficient way. The second is the way in which the central node will send the information received from the sensors to the CPU. The third is the implementation of the selection logic for checking the critical variables. In this project, the different ways of performing these processes were analysed and those that showed the most advantage were selected.

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Results

For the development of the HMI interface (Figure 5) where the information obtained from the sensors will be displayed, it was necessary to send the information through the serial port from the central node to the CPU. This information, regardless of the transmission medium, has to be structured in order to be interpreted by the HMI interface.

Three options are found to organize sensor information: generate an own structure or use one of the two most known data organization methods, which are JSON (Mora-Castillo, 2016) and XML (Skogan, 1999). In order to be able to work as a team and reduce development time, the creation of an in-house structure was discarded and the performance of each of the other two options was reviewed: JSON was chosen because it presents better overall performance in speed and consistent use of resources (Nurseitov, 2009). It is a widely used format, for working with database and transmission of information via web (Lv, 2019), in addition to having more ease of structuring, reading and processing data in LabView. This implementation can be seen in Figure 6.

Figure 5 HMI interface

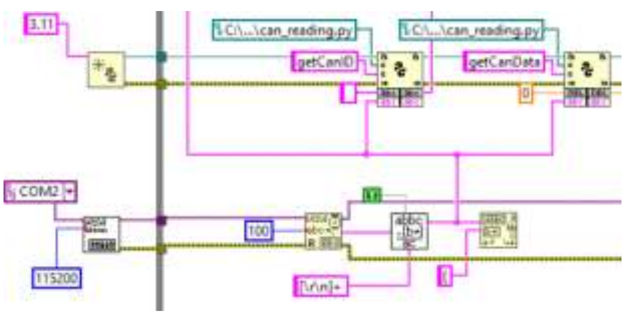

Figure 6 Reading from the central node

To receive messages through the serial port, a simple algorithm was developed to improve performance for this particular project, seeking compatibility with data packets in JSON format.

This communication consists of:

- Open the VISA serial communication
  - Selecting the corresponding COM port
  - Set the communication speed
- Using a reading node
  - Set the number of characters to be read
  - Eliminate the line breaks between each message
- Extract the necessary information
  - Open a Python node and set the version to use
  - Use function nodes
    - Specify the path to store the code
    - Specify the function name
    - Specify the type of data the function works on
- Sensor selection
  - Connect the output of the Python ID extraction node to the input of the case, to select the sensor with respect to its ID.
- Display message on flags
  - Connect the output of the serial communication after removing the line breaks to the text indicators.
- Display values on gauges
  - Connect the output of the Python value extraction node to the meter, and then evaluate whether the condition is met to give a status indication.

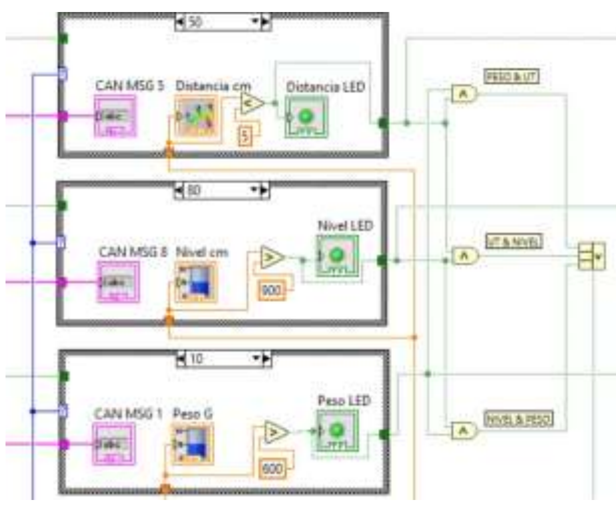

Figure 7 Sensor redundancy

Using the concept of redundancy (Cueva Tumbaco, 2019) in the sensors, which consists of giving each sensor an importance (weight) that is evaluated in a logical function, if the sensors that work correctly have sufficient weight to declare the system operational, the system enables the output to the actuator.

It is proposed that the sensors have the same importance, because of this the condition is created that two of the three sensors in charge of monitoring the state of the tank must be working correctly and give similar measurements (Figure 7), so that the switch that turns on the boiler is enabled, this switch is shown in the HMI interface (Figure 5).

Acknowledgement

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Conclusions

In conclusion, advances in virtual instrumentation have enabled the integration of CAN networks and microcontrollers in distributed sensor projects, providing efficient and reliable solutions for real-time data acquisition.

These technologies offer significant potential in a wide range of applications, from the electronics industry to industrial process monitoring and control.

There were no perceptible delays or drops in data, the microprocessors were programmed to turn on an LED in case they lost a packet of data, the tests lasted an average of 4 hours and there was no loss of data. Future tests are expected to apply methodologies to stress and push the network to its limit in order to characterise the robustness of this application.

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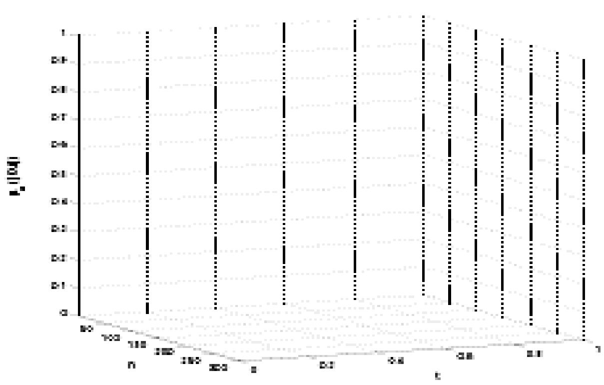

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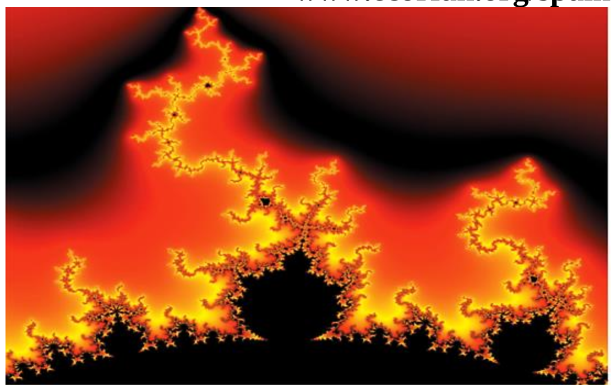

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