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Journal Computational Simulation

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Support the international scientific community in its written production Science, Technology and Innovation in the Field of Engineering and Technology, in Subdisciplines of telemetry, diffuse interval, electrical stimulation, diffuse controller, mobile application, communications network, web platform, production control, computer technology, computer electronics, control devices, programming languages and automated production systems.

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The works must be unpublished and refer to topics of telemetry, diffuse interval, electrical stimulation, diffuse controller, mobile application, communications network, web platform, production control, computer technology, computer electronics, control devices, programming languages and automated production systems and other topics related to Engineering and Technology.

Presentation of Content

The first article presents, *Power system restoration protocol for planned events in a real time simulator* by Galván-Sánchez, Verónica Adriana, Gutiérrez-Robles, José Alberto, Ortiz-Muro, Víctor Hugo and López-de Alba, Carlos Alberto, with adscription in Universidad de Guadalajara, as the next article is *Simulation of power grids using multirate methods* by Galván-Sánchez, Verónica Adriana, Gutiérrez-Robles, José Alberto, Bañuelos-Cabral, Eduardo Salvador and López de Alba, Carlos Alberto, with adscription in Universidad de Guadalajara, as the next article is *Professional residency web system implementing artificial intelligence model* by Diaz-Sarmiento, Bibiana, Román-Hernández, Esteban Daniel, Morales-Hernández, Maricela and Salinas-Hernández, Fabiola, with adscription in Instituto Tecnológico de Oaxaca, as the next article is *Interactive business card prototype: promoting brands with augmented reality on social networks* by Ortega-Gines, Héctor Bernardo, Hernández-Guzmán, Julieta, Colmenares-Olivera, Esperanza and Curioca-Varela, Yedid, with adscription in Universidad Tecnológica de Tehuacán, as the last article is *Advances in CPR: Design and Validation of the RescueBeat System for Compression and Ventilation* by Martínez-Torres, Rosa Elia, Mendoza-Razo, Juan Arturo, Padrón-Vázquez, Alejandro and Espinosa Juárez, Cid Tonatiuh, with adscription in Instituto Tecnológico de San Luis Potosí.

Content

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Article

Power system restoration protocol for planned events in a real time simulator

Protocolo de restauración de un sistema eléctrico para eventos planeados en un simulador en tiempo real

Galván-Sánchez, Verónica Adriana*[a], Gutiérrez-Robles, José Alberto[b], Ortiz-Muro, Víctor Hugo[c] and López-de Alba, Carlos Alberto[d]

[a] Universidad de Guadalajara • ADT-7409-2022 • 0000-0002-5462-2361 • 293960
[b] Universidad de Guadalajara • LMN-4565-2024 • 0000-0002-0276-0244 • 30264
[c] Universidad de Guadalajara • LMN-6141-2024 • 0000-0002-0276-0244 • 121660
[d] Universidad de Guadalajara • LMN-5894-2024 • 0000-0002-5914-9884 • 256222

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* ✉ [veronica.galvan@academicos.udg.mx]

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Abstract

This work presents the analysis of planned events in an electrical power network to establish the optimal system restoration protocol for recovering an electrical system. First, a technical description of each maneuver is provided, along with the operational protocol that is followed to decide whether or not it is feasible to carry it out. Once the decision is made to proceed, the preparation of the electrical network is demonstrated. To ensure that all those involved in the technical operational aspect follow a standard reconnection procedure, each event is simulated in the simulator, and the restoration sequence chosen by the person being evaluated is analyzed to determine whether the sequence followed is appropriate or if any specific steps could have been avoided and/or modified. Finally, an assessment is made to determine whether the person being evaluated is ready to operate the network live or if they need more training hours on the simulator. In this way, the simulator becomes an additional tool to the one-on-one teaching that is passed from an operator to their assistant until the latter is capable of operating the network on their own.

Objetives	Methodology	Contributions
Analysis of the elements of the electrical power system. **Analysis of the general conditions of the power system.** **Analysis of the operation of the power system in view of planned events.** **Analysis of the operation of the power system in view of planned events.** **Analysis of the abnormal operation regime facing intentional events.**	**Follows the next steps:** **Element restoration sequence.** **Voltage and frequency control during a planned maneuver.** **Restoration maneuvers.**	**Training performs all restoration maneuvers, in the simulator, correctly; this does not indicate that you are already 100% trained to operate on the live network because stress management is different knowing that if you make a mistake nothing really happens.** **Testing real events to compare what an operator did under stress with what even the same operator would do in a more controlled environment such as real-time simulation.**

Real time simulator, Power system restoration, Connecting and disconnecting protocol

Resumen

Este trabajo presenta el análisis de los eventos planeados en una red eléctrica de potencia para establecer el protocolo de restablecimiento óptimo de recuperación del sistema eléctrico. Primero se hace una descripción técnica de cada maniobra y el protocolo operativo que se sigue para decidir si es factible o no llevarla a cabo; una vez que se toma la decisión de llevarla a cabo, se muestra como se prepara la red eléctrica. A fin de que todos los involucrados en la parte técnica operativa sigan un estándar de reconexión, se simula cada evento en el simulador y se analiza la secuencia de restablecimiento que elige la persona que se está evaluando para después analizar si la secuencia que se siguió es adecuada o si se pudo evitar y/o modificar algún paso especifico. Finalmente se califica si la persona que se está evaluando ya está en condiciones de operar la red en vivo o si necesita más horas de capacitación en el simulador. El simulador así se vuelve una herramienta adicional a la enseñanza uno a uno que se transmite de un operador a su ayudante hasta que esté está en condiciones de operar la red por sí mismo.

Objetivos	Metodología	Contribuciones
Análisis de los elementos del sistema de energía eléctrica. **Análisis de las condiciones generales del sistema eléctrico.** **Análisis del funcionamiento del sistema eléctrico ante eventos planificados.** **Análisis del funcionamiento del sistema eléctrico ante eventos planificados.** **Análisis del régimen de operación anormal ante eventos intencionales.**	**Sigue los siguientes pasos:** **Secuencia de restauración de elementos.** **Control de tensión y frecuencia durante una maniobra planificada.** **Maniobras de restauración.**	**El entrenamiento realiza correctamente todas las maniobras de restauración, en el simulador; esto no indica que ya estés 100% capacitado para operar en la red en vivo porque el manejo del estrés es diferente sabiendo que si te equivocas realmente no pasa nada.** **Probar eventos reales para comparar lo que hizo un operador bajo estrés con lo que haría incluso el mismo operador en un entorno más controlado, como una simulación en tiempo real.**

Simulación tiempo real, Restauración de sistemas de potencia, Protocolo de conexión y desconexión

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Introduction

Since electrical systems are constantly changing, and the components of a network, as well as their control systems, adapt to modern times, the planning strategies adopted by each control center also evolve, allowing for the continuous development of procedures, rules, tests, and experiences that describe the operating philosophy of electrical systems (Official journal of the federation). In the daily operation of an electrical system, the focus is on maintaining power quality parameters, such as voltage level and frequency. As part of this operation, scheduled maintenance work is coordinated, always ensuring the system's safety.

Despite these precautions and the continuous monitoring of the electrical system, disturbances occur unpredictably, leading to the loss of a network element, a section, or the entire system. As a result, a protocol for disconnecting and restoring elements is followed as part of the routine tasks of a network operator. During the brief period of a planned disconnection, the operator is simply an observer. However, once the event occurs, the operator is left with a section of the network in an unbalanced state. Thus, the operator's primary task is to bring the electrical system from this point to full recovery, relying on their knowledge and skill to execute manoeuvres that restore the system while staying within operational limits (Jacob, R. A. et.al.).

Although all control centers are committed to the continuous training of their personnel, the lack of a detailed description of the steps to follow for system recovery after a disturbance—whether or not it results from a planned event—places this responsibility on the operator in charge. However, the person on duty must have the ability not only to restore the system but to do so reliably and in the shortest possible time.

Currently, one of the most efficient testing protocols is based on real-time simulators in their different forms, that is, using the closed loop between two simulated systems (software in the loop - SIL), creating the interface between two physical elements that they simulate (hardware in the loop - HIL), or by creating the interface between a device and the computer (Rapid control prototyping - RCP).

Among the most common or well-known simulators are RTDS (Real Time Digital Simulator) and E-MegaSym Real Time. Both have the versatility to simulate in the three ways previously stated. Another strategy is the one used in personnel training, where simulators are used that emulate specific events and the person to be trained interacts with said simulator.

The best known are flight simulators and/or some that are even used as part of a hobby or fun, such as simulators to drive anything from a simple element like a bicycle to something complex like a combat helicopter. Of course, the closer the virtual reproduction is to reality, the better the training is or rather the more effective this training will be because the interaction between the person and the machine is practically real, that is, it requires the person to perform the necessary same movements and subjects it to the same stress as if it were a real event (Krpan, M. et.al).

The National Energy Control Center (CENACE) in Mexico uses a simulator called ORACLE, this simulator has the energy network and updates it from time to time. In it, phenomena or events can be reproduced, whether past (real), or fictitious by programming them. Additionally, the state of the network can be monitored in real time. The events for training, whether real or fictitious, develop at the speed and in the sequence in which they would physically occur, in such a way that by being able to interact with the system, the measures or decisions taken will lead to the recovery of the system or its destruction collapse; this is the way in which the personnel to be trained are tested without putting the system at risk but emulating the state of both the network and the environment that surrounds it.

For this to happen, the personnel dedicated to training know perfectly well what they must do to recover the network, however, since the sequence of maneuvers to bring the network to a new stable state is not unique, only the performance can be evaluated of personnel to be trained until the entire operation has been completed.

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It is the case, when there are past events, where a network operator made all the maneuvers for recovery, that in the simulator are emulated as if they happened again with such precision that if the same sequence of maneuvers is followed, it is recovered in virtual form the network; however, different sequences can be tested to evaluate if the most appropriate was done since the energization sequence can result in both users and energy generation companies not being operational for a period of time (second, minutes or more) that is translates to economic losses. Although in the strict sense, since there is no restoration protocol, since the events in a network are n-exponential, network operators in a state of stress at the limit are trusted to do the best they can for the condition they have (Wu, H. et.al) and (Verma, S. & Chelliah, T. R.).

Elements of the electrical power system

From an operational point of view, it can be considered that the most important elements are the generators, lines, transformers, switches and loads. Below is a technical description of the limitations of each of these elements.

Operating limit of a generating unit

Generating units play an important role in the electrical power system, not only because of their generation, but also because of their ability to control voltage levels in nodes or important areas surrounding them. The generators are dispatched according to their fuel availability, whether fossil fuel, gas, water, etc. In addition to environmental and social conditions, for example, the pollution associated with thermoelectric plants and the impact of using or not using hydraulic units when dams have high or low reservoir levels. Thermoelectric units are generally dispatched at their maximum capacity, although the trend is to change to combined cycle units, which are very efficient units with very little environmental pollution. Generators cannot take maximum load instantly, this limits their operation according to their power and type, for example: for a hydroelectric generating unit, its load taking depends greatly on its type of turbine, as well as its generator, but for a common 320 MW hydroelectric generator it will take 25 MW per minute for the first 2 approximately and increases until it takes 60 or 70 MW/min for the next 5 minutes until it reaches its maximum value or the one requested.

On the other hand, in the case of a thermoelectric generator its load taking capacity at start-up is very slow compared to a hydroelectric generator, this for example starts with just 5 MW/min and can reach 10 MW/min for more efficient machines; so, they take a long time to reach their maximum level.

Operating limit of a transformer

A power transformer has a typical flux-current magnetization curve as shown in Figure 1. To avoid having so many losses, it works below the inflection point indicated in this figure with the intercept of the dotted lines, that is, in its linear and most efficient area. Figure 1 clearly shows that from that point on, the current can be increased considerably but the concatenated flux increases very little, for this reason the transformer is limited to working outside that zone.

Box 1

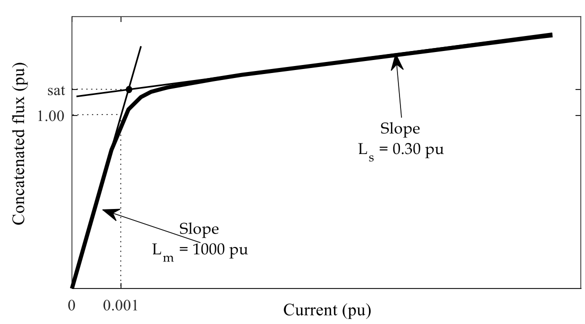

Figure 1
Magnetization curve of flux-current for a power transformer
Source: Own elaboration

The two main causes of surges due to transformer connection/disconnection are transformer energization and the effect of load rejection, both events are described below.

Energization

When a transformer is energized, a large amount of harmonic-rich inrush current can flow, which depends mainly on the point of the voltage wave applied to the transformer at the instant of energization, the remaining flux of the transformer, and its reactance air core. Transformer voltage waveforms for a representative case are found in figure 2.

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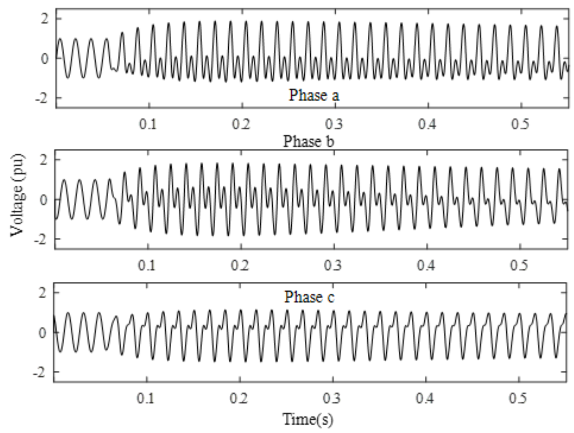
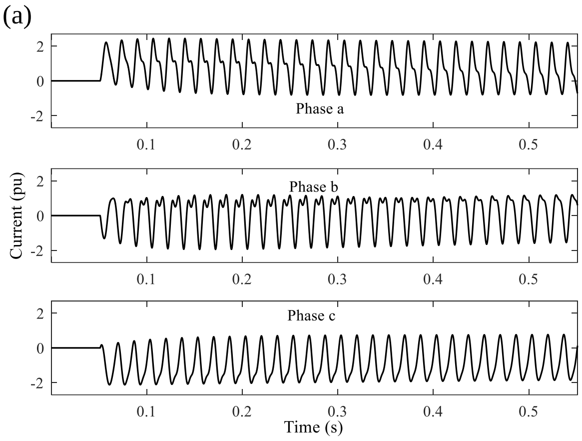
Figure 3 shows a harmonic analysis over time for phase A of the inrush current; the others behave in a similar way. It is observed that the inrush current has a high second harmonic content in addition to its fundamental and dc component; third, fourth and fifth harmonic components with considerable amplitude are also generated.

Box 2



(a)



(b)

Figure 2
Voltage and current waveforms during the energization of a 500 MVA transformer in a system with an inrush current of 2.5 kA: (a) Currents, (b) overvoltages at the transformer terminals.

Source: Own elaboration

Box 3

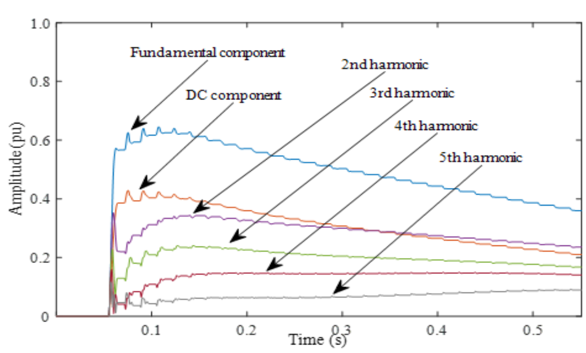


Figure 3
Harmonic components of the inrush currents for phase a

Source: Own elaboration

Load rejection

When a load at the end of a transmission line is disconnected, it generates excess reactive power, leading to temporary surges in the electrical system. These surges depend on the short-circuit power at the load connection point, the magnitude of the rejected load, and the reactive power of the line, which in turn depends on the line parameters. The analysis of these over voltages is especially important if resonance effects occur due to the interaction of capacitive elements and inductive elements with a non-linear characteristic (Das, J. C.) and (IEC/IEC 60099-5). In general, a system with relatively short lines and high short circuit power will have low surge voltages, while a system with long lines and low short circuit power will have high surge voltages (Das, J. C.) and (IEC/IEC 60099-5). The time these surges last depends on the type of generators (Das, J. C.), (IEC/IEC 60099-5) and (CIGRE Working group 06). Since the voltage at the receiving end of the line is kept at 1 pu, the voltage behind the equivalent impedance of the system increases with the load current, which is directly proportional to the load power. Thus, since the source voltage is proportional to the load, the larger the connected load, the greater the surge voltages are expected to occur. The zero-sequence impedance has an influence on over voltages due to the different opening times of the switches, and this influence is marked in the first moments of disconnection. Therefore, for a system with a higher zero sequence impedance the surges are higher.

Operating limit of a transmission line

The two operational limits that exist within transmission lines are the energy transmitted (MVA) or the amperes. There is a limitation of the MVA's due to the construction of the line itself (avoid heating) or in other cases due to lines with long line classification, due to stability margin (Sybille, G.). The other limitation (amperes) is due to the measurement capacity of the primary equipment (current transformers). When the network is in normal conditions, due to the effects of the load zones and network topology, when any link tends to be overloaded, CENAL makes the decision to modify the generation or open lines as appropriate. When the network is already in a stressed condition, the operator reviews its flows in real time and upon observing an overloaded line, tries to resolve it, making the decision to modify the network by opening or closing transmission lines.

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Opening and closing switches

The switches are mechanical systems that disconnect the elements of the SEP, although they have an action time of a few milliseconds, for the purpose of planned maneuvers they do not cause any additional problem to the SEP, for this reason within the connection/disconnection protocol they are considered passive elements, that is, with ideal performance.

General conditions of the power system

An electrical power system serves as a means of transport for energy but cannot store it, for this reason there must be a balance between generation and load at all times.

Naturally, if the load is at the maximum generation limit and in addition the lines are transporting the maximum amount of energy they support, the system is at a point where even a planned maneuver can trigger a sequence where it can be a general collapse.

The operational constraints of generation, transmission, transformation and design are associated with steady state limitations, transient stability (angular), transient voltage stability and long-term stability; characterized by maximum and minimum limits.

Box 4

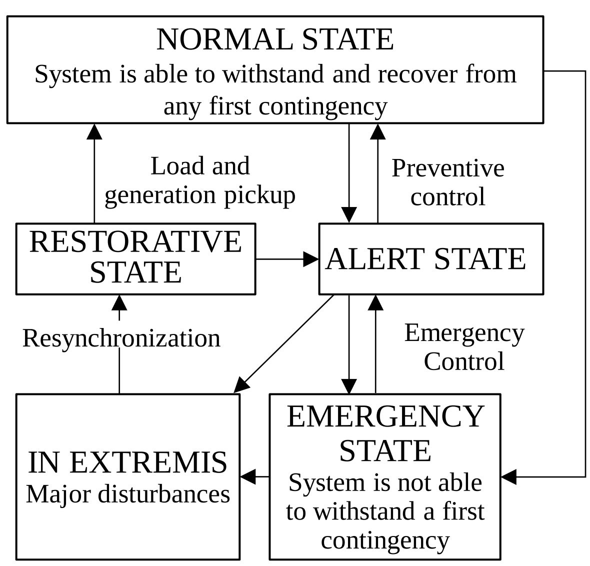

Figure 4
PES states

Source: Own elaboration

Operating states of the electrical power system

Due to the dynamics that exist between the different members of the electrical industry and the general restrictions or limitations (operational and design) that may be present when operating the national electric system (NES), which implies operating outside of operational, reactive reserve, voltage levels, transmission and transformation capacity among others, four operational states were established. As a consequence of the set of restrictions, five operating states can be identified as shown in figure 4, each of them is described below.

Normal state. - In this state, the electrical system operates with sufficient reserve margins in generation, transmission and transformation, to comply with the concept of security in the event of possible simple contingencies that may arise. Post-contingency, the electrical equipment must remain operating within its permissible limits, both operational and design, and must not present a loss of charge.

Alert state. - In the alert operating state, all the variables of the NES are still within their operational limits, however, in the event of a contingency, the NES can continue to be stable without the action of the supplementary control schemes or, it can lead to the emergency operating state in which the system is at potential risk of instability.

Emergency operating state. - In this state, it operates below the established reserve limits. Equipment operates outside its operating and design limits. Load affectation either by the operation of a protection scheme or manual load pull. In this state, the occurrence of a more severe simple contingency will lead the NES to a condition of instability and operation in this state requires the execution of remedial actions.

Restorative state. - The electrical islands that remain active will supply a part of the total demand with the equipment operating within its design limits. In this state, all control efforts must be focused on reintegrating the system and supplying the total demand in the shortest possible time.

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Operating characteristics of a generating plants

In the normal operating state, to achieve reliable operation of the electrical system in the load-generation balance, a reserve of rolling and cold generation is required available at any time to maintain the frequency in the programmed quality band, satisfy variations in demand and avoid affecting the load and operation of the turbo generators outside the design limits.

Before a planned maneuver, each control area must identify strategic generating plants contemplated in the restoration plans in the event of a general or partial collapse in which the installation is required (if it is not available) of the necessary equipment to have the “black startup” capacity. This guarantees the supply and quality of energy in the event of the most severe simple contingency after the planned maneuver.

Operation of the power system in view of planned events

A planned event has an economic cost and an operational cost, each of them is evaluated in order to decide if the maneuver is feasible and safe, a brief description of both is provided in the following paragraph.

According to available resources

The resources available largely dictate whether a planned operation can be carried out or not, the protocol to follow is described below:

1. The need for preventive/corrective maintenance, commissioning or modifications is detected and the request is made to CENACE.

2. They send license applications to CENACE for evaluation and authorization, complying with the established requirements. A registration number is assigned to the request.

3. CENACE carries out the preliminary evaluation of the license application in the requested scenario, in its area of responsibility.

4. CENACE carries out the first contingency security analysis on the network associated with the license request.

5. If feasible, CENACE authorizes the license application under the required conditions, notifying the applicant.

6. If it is not feasible to authorize the application, CENACE reschedules the application, in common agreement with the applicant. If an agreement is not reached, the application is canceled and the applicant must apply for a new application.

7. The applicant defines the moment in which they are prepared to start live or dead work that requires taking the equipment out of service and/or requesting to initiate a maneuver from the control center.

8. The applicant verifies previous operating conditions and requests from the CENACE operator authorization to begin executing the maneuver associated with the request, whether scheduled or emergency.

9. CENACE evaluates and adjusts the operational conditions required to execute the maneuvers associated with the scheduled or emergency request. If the above is not possible, the application is rescheduled and/or canceled with the proper justification established in the license application.

10. Prior to starting a maneuver, CENACE will deliver a license to the applicant and authorize the execution of maneuvers associated with the request. If necessary, CENACE will coordinate the execution of the maneuver.

11. Execute the maneuvers to release the equipment requested in the license. They record the schedules of each of them.

12. The applicant notifies the CENACE operator of the end of the maneuvers.

13. The applicant reports the completion of the work, and requests authorization to begin a maneuver to normalize the licensed equipment.

14. CENACE confirms completed work and withdraws the license.

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15. CENACE verifies and adjusts the operating conditions necessary for the standardization of the equipment, and authorizes the execution of maneuvers or, where appropriate, indicates from what time the maneuvers can be carried out.

16. The applicant normalizes the equipment by executing the maneuvers according to the maneuver catalog.

According to the operating cost

Each element of an electrical network has a weight in the stability and control of said network; this weight can be measured with a sensitivity study and will depend on the network connectivity. For this reason, disconnecting equipment has a different impact (operating cost) depending on the state of the network. In this way, operators heuristically evaluate the risk of disconnecting equipment for maintenance; this evaluation is supported by contingency studies to verify if the network supports the disconnection of said equipment, however the impact of this disconnection can only be evaluated by the operator on duty in such a way that he has to decide what is the most appropriate moment (of lesser impact) to make the release. There are emergency maneuvers that must be carried out at the moment they are requested by people from other departments, even so if the operator on duty determines that it is not feasible, it is agreed with the others involved to carry it out as soon as possible depending on the situation equipment failure.

Abnormal operation regime facing intentional events

The 5 fundamental elements in an electrical power system are the lines, the generators, the transformers, the switches and the loads. In general terms, each element is disconnected and/or connected according to the arrangement of switches available, so when It is necessary, whether due to maintenance or failure, to disconnect and/or connect some SEP equipment, a sequence must be followed for each element, coordinated in real time by the SEP operator and verified at all times, in each substation. by its operator. The oscillations that the maneuver may cause are monitored at all times by the operator; In the event of a contingency or abnormality in the network, he will have to decide, immediately, to continue or suspend the maneuver.

Output sequence of a SEP element

LINE: To carry out the programmed disconnection of a transmission line, the steps may vary according to the switch arrangement, for example, in the case of a simple switch, the following steps are followed:

1. The first maneuver is to deenergize the line using the switches that can extinguish the electric arc that may occur. In this step it is important to decide in which substation to open the line first, since for a few minutes there will be an empty line, which generates reagents causing a rise in the voltage to which it is still connected.

2. The blades at both ends of the line are opened.

3. Both ends of the line are grounded using blades to de-energize it. This completes the disconnection maneuver of a transmission line.

GENERATOR: When a generator needs to be disconnected, the power plant operator must give a stop pulse to the generator. With this pulse, the first thing he does is open the machine switch. When this happens, he begins to stop the rotor. When this ends, own services begin to be disconnected and finally some generators are grounded.

TRANSFORMER: As in the lines, the disconnection maneuver of a transformer is based on the arrangement of switches that it has, for example, for a simple switch the following sequence of maneuvers is followed:

1. The switch on the low voltage side is opened because the current reflections for the high voltage side will be of lower magnitude, and the electric arc on the low voltage side will be of lower amplitude.

2. The high voltage switch opens.

3. The blades of both switches are disconnected. This concludes the disconnection sequence of a power transformer.

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SWITCH: The procedure to de-energize a switch varies according to the arrangement of switches that are used, the most common is to transfer the load that the switch that is to be de-energized is taking to another switch called “wildcard”, the procedure is as follows:

1. The “wildcard” switch blades are closed (which should normally be open as well as the switch), as well as the transfer blade of the switch that will be de-energized is closed.

2. The “wildcard” switch is closed, after which the switch that will be released is opened. It is worth mentioning that when the transfer blade in step 1 is closed, the switches own protections are transferred to the “wild card” switch.

3. Finally, only the switch blades are opened to complete the de-energization. In the case of a double or half switch arrangement, it will be enough to open the switch as well as its side blades.

LOAD: In emergency conditions of the National Electrical System, the only one authorized to disconnect load is the National Energy Center. There are several types of cargo, among them the so-called Interruptible Cargo, which is cargo that can be interrupted totally or partially in accordance with the provisions of the current rates. In times of emergency, the load pull is the last resort that should be taken by the operators, but in the case of a planned load pull, it must be announced to the interested party days in advance. It will be enough to open switches or blades under load in the control area.

Element restoration sequence

LINE: To restore a transmission line, the steps may vary, as in the case of disconnection, according to the arrangement of switches, for example, in the case of a simple switch, the following steps are followed:

1. As a first step, you must remove all physical soil as well as open the ground blades.

2. Next, the blades are closed at both ends of the line.

3. You must choose which node the switch closes first, taking into account its electrical robustness since there will be a line empty for a moment of time or in another case you may have a line with a fault or some element. ashore. Afterwards, the other switch is closed, having already an energized line. This completes the connection maneuver of a transmission line.

GENERATOR: It begins with reestablishing all the generator services. The generator begins to run, and upon reaching the plate RPM, synchronization with the National Electrical System is carried out through the machine switch.

TRANSFORMER: As in the lines, the energization maneuver of a transformer is based on the arrangement of switches that it has, for example, for a simple switch the following sequence of maneuvers is followed:

1. It is verified that all the switches associated with the transformer are open, once this the blades of the switches are closed.

2. The high voltage switch is closed.

3. The low voltage switch is closed. This concludes the energization sequence of a power transformer.

SWITCH: The procedure to energize a switch that is used as a wildcard switch is as follows:

1. For safety reasons, it is verified that after work the switch has been left open, once this is confirmed, the switch's own blades are closed.

2. The switch is closed.

3. The “wildcard” switch opens. Once open, its side blades open as well as the so-called transfer blade of the switch that was energized.

LOAD: To restore the disconnected load, it is enough to command the closure of the switch from the control room, as in the case of a knife under load, if you have control in the room, or do it from the substation panel.

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Voltage and frequency control during a planned maneuver

To guarantee reliable and safe operation of the interconnected system, the control zones in coordination with CeNal must control the generation, supply and administration of reactive power resources. The system must be operated with an adequate voltage profile and maintain a sufficient reactive power reserve margin in generation sources and static VAR compensators, in such a way that in the event of the most severe simple contingency, after a planned maneuver, the system is stable. In the event of contingencies due to a planned event, the supply of reactive power must be automatic; manual actions to support and control the network voltage profile are not recommended. Before a maneuver, to guarantee that the supply and quality of the energy will not be lost, it is monitored that:

1. The transmission lines are in service and can only be disconnected for voltage control if electrical studies show that the reliability of the system does not degrade significantly.

2. It is necessary that the reactors and banks of shunt capacitors be provided with switches to avoid de-energizing other facilities, when it is required to connect or disconnect them for voltage control.

3. All generating units must have the capacity to generate/absorb reactive power according to their capability face. Likewise, be equipped with automatic voltage control equipment and operated in this control mode for as long as possible.

Analysis of recovery events

The simulator has the function of emulating PES events in such a way that the recreation of these events serves to follow the performance of a person virtually operating the network. Possible events and/or events that have already occurred in the electrical system are proposed. This simulator has the peculiarity that it has the network diagram so that past events can be simulated and verify if the live maneuvers were the most appropriate to recover the network, in this way not only the personnel are trained but also verifies the efficiency and effectiveness of the operators.

Figure 5 shows the test network used in the real-time simulator, this network is similar to the real network in the western area of México, where operators and/or future network operators are trained. Below is a description of events and the maneuvers that the person in training followed to recover the network. In this network, the event to be simulated is associated with an average load similar to that of a normal day of operation. The simulator takes this data directly from the real network and is simply saved in a file that can later be recovered in the simulator to do the training.

Event B6 AT-04

The network condition is that all flows from nodes marked as generation are incoming except those marked with B71 and B36. In this condition, the simulator operator generates a fault in one of the two transformers (AT-02) of the substation marked as B6, immediately leaving the other transformer marked as AT-03 at 138% of its nominal capacity. It should be noted that the load and generations of the network are kept intact, and only the necessary maneuvers need to be made to reorient the flows.

Restoration maneuvers

The person who is in the simulator and is training must do all the maneuvers to recover the adequate condition of the network. The maneuvers they perform will immediately affect the network, just as would happen if they were operating it live; this person performs the following reset sequence.

1. Open the switch (marked with 1 in an orange box) of one of the lines that goes from B6 to B56 to transfer part of the load from B6 to B66, with this maneuver the AT-03 transformer of the substation B6 drops to 134% of its nominal capacity.

2. Open the switch (marked with 2 in an orange box) of the other line that goes to B66 (line B6-B56) to transfer that part of the load to the B66 substation, with this maneuver the AT-03 transformer drops to 127% of its nominal capacity.

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3. Open the switch (marked with 3 in an orange box) of the line that goes from B52 to B44 and thus load is transferred to substations B2 and B5; with this maneuver, the flows are redirected and the condition of the network is as follows: AT-03 is at 90% of its nominal capacity, B2 at 76% of its nominal capacity, and B5 with overload at 113% of its nominal capacity. nominal capacity.

4. Open the switch (marked with 4 in an orange box) of the line that goes to B36 to discharge B5 in such a way that in the reorientation of flows no transformer remains above its nominal capacity, thus recovering the condition adequate network 100%.

Box 5

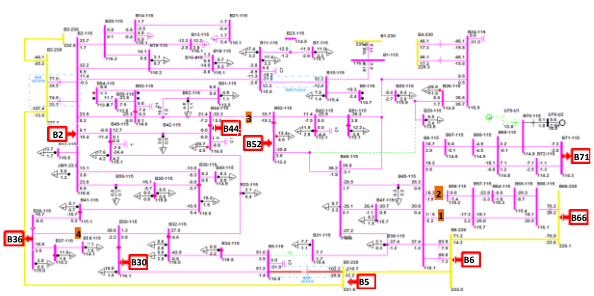

Figure 5
Network used in the real-time simulator for event AT-02 of substation B1

Source: Own elaboration

Event B6 AT-03

The 230 kV and 115 kV electrical network shown in figure 6 is in normal operating conditions. It is proposed to recreate a real event in the simulator. On the day of the event, there were no reports of rain or strong winds in the area; The load of the transformers was as follows: B6-AT-01 at 83%, B6 AT-02 at 86%, B5 at 101%, B66 at 63%, B2 AT-01 at 87% and B2 AT- 02 at 84%. At 16:59 on the day in question, the switches connected to B6 AT-03 trip, due to the operation of protections 86 and 87 (differential and overcurrent relay respectively). In the event, the low side of B6 AT-04 trips due to protection operation 51.

The disturbance affects 23.5 MW due to operation of the low voltage protection scheme (27's – low voltage relay) by tripping the low side of the transformers of the following substations: B43, B67 and B69 when voltages of 102 kV are present.

The event is recreated in the real-time simulator for training purposes; The person conducting the training makes all the disconnections simulating the operation of the relays. In this way, the real conditions of the event are obtained and from there the restoration begins. The person to be trained performs the following maneuvers to recover the network.

Restoration maneuvers

The person who is in the simulator and is training must do all the maneuvers to recover the adequate condition of the network, the final conditions after the event are: B66 at 127%, B5 at 124% and B2 at 120%. The flow of the line from B44 to B52 is 33 MW and the flow from B57 to B6 is 65 MW. As a B6 AT-04 overload trip (160%) and 23.5 MW were affected by operation of the 27's; several maneuvers can be done such as: closing IN-72040 in B6, pulling load to be sure that when closing B6 AT-04 it will not trip again due to overload, or trying to restore the affected load before putting B6 AT-04 into service. The trainee performs the following reset sequence.

1. Closes IN-72040 in B6 (marked with 1 in an orange box) leaving AT-04 with an overload of 130%, in S.E B66 AT-01 remains with 72%, in S.E B5 AT-01 with 108 % and the S.E B2 AT-01 and AT-02 with 88%.

2. To unload in the S.E B6 AT-04, the 115 kV network is disconnected, the operator opens the switch (marked with 2 in an orange box) of one of the lines that goes from B6 to B57 with this maneuver. AT-04 transformer presents 122% overload.

3. Operator opens the switch (marked with 3 in an orange box) of the line that goes from B6 to B56 in the B6 substation, with this maneuver the B6 AT-04 transformer is left with a 105% overload, modifying the B66 loading to 92%.

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4. If the affected load is restored in this condition, B6 AT-04 would be overloaded again with tripping possibilities, therefore, the operator opens the switch (marked with 4 in an orange box) of the line that goes from B52 to B44 at substation B52. With this maneuver, the transformers are loaded as follows: B6 AT-04 73%, B66 92%, B5 117% and B2 94%.

5. With the previous maneuver, the S.E B5 AT-01 was overloaded with 117% of nominal capacity. Operator opens the switch (marked with 5 in an orange box) of line B30-B36 of substation B30 in order to discharge B5. The transformers are as follows: B6 AT-04 73%, B66 AT 01 with 92%, in S.E B5 AT-01 with 104% and S.E B2 AT-01, 02 at 100%.

6. The load affected by the operation of protection 27 is restored, the final state of the transformers is: B6 AT-04 99%, B66 AT-01 at 92%, in B5 AT-01 at 104% and in B2 AT01, 02 at 100%.

Box 6

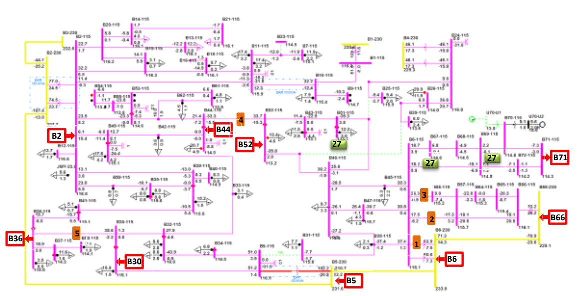

Figure 6
Network used in the real-time simulator for event AT-03 of substation B6

Source: Own elaboration

Event B5 AT-01

The 230 kV and 115 kV electrical network shown in figure 7 is in normal operating conditions. It is proposed to recreate a real event in the simulator. On the day of the event, there were no reports of rain or strong winds in the area; The load on the transformers was as follows: B6-AT-03 at 83%, B6 AT-04 at 86%, B5 AT-01 at 101%, B66 AT-01 at 63%, B2 AT-01 at 87% and B2 AT-02 at 84%. The person doing the training operates protection 86 and 87 of transformer B5 AT-01, this indicates that this transformer goes out of service and cannot be recovered.

Due to the disturbance, the operation of the system protection scheme due to low voltage (27's) is affected by tripping the low side of the B34 substation transformer when voltages of 103 kV are present. With the disturbance, the load on the transformers remains as follows: B6-AT-03 at 89%, B6 AT-04 at 92%, B5 AT-01 at 0%, B66 AT-01 at 65%, B2 AT- 01 at 121% and B2 AT-02 at 117%.

Restoration maneuvers

The person who is in the simulator and is training must do all the maneuvers to recover the proper condition of the network by performing the following restoration sequence.

1. Open the switch (marked with 1 in an orange box) from line B46 to B38 on B46. This maneuver prepares the network for the next one. This maneuver is to avoid overloading the line from B6 to B38 with the closure of the switch (marked with 4 in an orange box) on S.E B31.

2. Open the switch (marked with 2 in an orange box) from line B6 to B56 in B6, with this maneuver the flux in the transformers is: B6-AT-03 at 80%, B6 AT-04 at 83%, B5 AT-01 at 0%, B66 AT-01 at 74 %, B2 AT-01 at 124% and B2 AT-02 at 120%. With this maneuver the network is prepared so as not to overload the AT in B6.

3. Open the switch (marked with 3 in an orange box) from line B6 to B57 in B6, with this maneuver the flux in the transformers is: B6-AT-03 at 69%, B6 AT-04 at 71%, B5 AT-01 at 0%, B66 AT-01 at 90% %, B2 AT-01 at 123% and B2 AT-02 at 119%. With this maneuver the network is prepared so as not to overload the AT in B6.

4. Close the switch (marked with 4 in an orange box) from line B31 to B5 at substation B31. With this maneuver, the direction of the flows is changed by reorienting a part that left B6 to substation B5. With this, the transformers are charged as follows: B6 AT-01 at 93%, B6 AT-02 at 96%, B5 AT-01 at 0%, B66 AT-01 at 90%, B2 AT-01 at 100% and B2 AT-02 at 98%.

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5. The load affected by the operation of relays 27's of substation B34 is restored, leaving the load on the transformers as follows: B6-AT-03 at 97%, B6 AT-04 at 100%, B5 at 0%, B66 at 90%, B2 AT-01 at 104% and B2 AT-02 at 100%.

Box 7

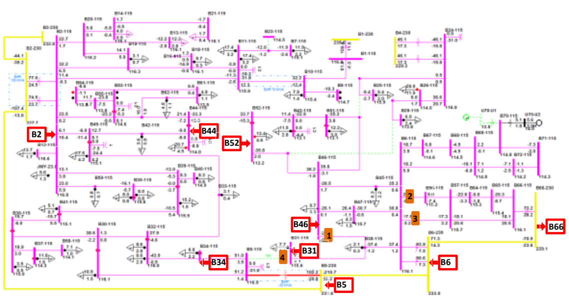

Figure 7
Network used in the real-time simulator for event AT-02 of substation B1

Source: Own elaboration

Conclusions

Normally the passing of knowledge one by one and acquiring experience in the field is what leads operators to be able to respond instantly in any operating condition; however, one strategy is training in real-time simulators that emulate the network. In this sense, the following was found:

1) The simulator is an appropriate tool to acquire skills in network operation.

2) When a person in training performs all restoration maneuvers, in the simulator, correctly; this does not indicate that you are already 100% trained to operate on the live network because stress management is different knowing that if you make a mistake nothing really happens.

3) However, if the person in training cannot correctly perform the appropriate maneuvers to restore the network, this does indicate that the person is not yet qualified to operate live regardless of his or her ability to handle stress.

4) By testing real events, you can compare what an operator did under stress with what even the same operator would do in a more controlled environment such as real-time simulation.

Conflict of interest

The authors declare no interest conflict. They have no known competing financial interests or personal relationships that could have appeared to influence the article reported in this article.

Author contribution

Galván-Sánchez, V. A.: Wrote the article.

Gutiérrez-Robles, J. A.: Development the simulations y made the figures for the article.

Ortiz-Muro, V. H.: Review, generate and selection of the examples and/or results presented in the article.

Lopez-DeAlba, C. A.: Review of the content and putting the article into format.

Availability of data and materials

All the results that are obtained are in the article and can be accessed freely depending on the journal's policies.

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Abbreviations

CENACE	The National Energy Control Center
CENAL	National Control Center
EPS	Electrical Power System
HIL	Hardware In The Loop
MVA	Mega Volts Ampere
MW	Mega-Watts
NES	National Electric System
ORACLE	Company specialized in the developed of cloud and local solutions
RCP	Rapid Control Prototyping
RTDS	Real Time Digital Simulator
SIL	Software In The Loop

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DOI: https://doi.org/10.35429/JCS.2024.8.19.1.13

References

Antecedents

CIGRE Working Group 06 of Study Committee 33 (Overvoltages and Insulation Co-ordination). Metal Oxide Surge Arresters in AC Systems. 1991.

Basics

Krpan, M., Wang, X., Beus, M., Parisio, A., & Kuzle, I. (2024). Distributed control of a virtual storage plant for frequency restoration services: An experimental validation. *International journal of electrical power & energy systems*, *159*, 110031.

Official journal of the federation. (Network Code).

Wu, H., Xie, Y., Deconinck, G., Yu, C., Hou, K., Sun, J., & Jia, H. (2024). Distributed Coordinated Restoration of Transmission and Distribution Systems with Repair Crews and Mobile Emergency Generators. *IEEE Transactions on Power Systems*.

Supports

DAS, J. C. Transients in electrical systems. McGraw-Hill, 2010, ISBN:978-0-07-162603-3.

Verma, S., & Chelliah, T. R. (2024). Restoration of extra-high voltage power grids through synchronous and asynchronous hydro units during blackout—A comprehensive review and case study. *Electric Power Systems Research*, *228*, 110054.

Differences

Jacob, R. A., Paul, S., Chowdhury, S., Gel, Y. R., & Zhang, J. (2024). Real-time outage management in active distribution networks using reinforcement learning over graphs. *Nature Communications*, *15*(1), 4766.

Discussions

IEC/IEC 60099-5, International Standard. Surge Arresters-Part 5: Selection and application recommendations. 1999.

Sybille, G. Single-Phase Series Compensated Network. The MathWorks, Inc., published with MATLAB® 7.9. 2015.

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Article

Simulation of power grids using multirate methods

Simulación de redes eléctricas mediante métodos multitasa

Galván-Sánchez, Verónica Adriana*[a], Gutiérrez-Robles, José Alberto[b], Bañuelos-Cabral, Eduardo Salvador[c] and López de Alba, Carlos Alberto[d]

[a] Universidad de Guadalajara • ADT-7409-2022 • 0000-0002-5462-2361 • 293960
[b] Universidad de Guadalajara • LMN-4565-2024 • 0000-0002-0276-0244 • 30264
[c] Universidad de Guadalajara • AAF-2785-2021 • 0000-0002-6004-5898 • 241756
[d] Universidad de Guadalajara • LMN-5894-2024 • 0000-0002-5914-9884 • 256222

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* [veronica.galvan@academicos.udg.mx]

Abstract

This article describes a methodology based on Gabriel Kron's diakoptics technique for efficiently simulating an electrical network. The methodology involves dividing a large electrical network into subnetworks that are decoupled in time from each other. For the purpose of network division, it is assumed that the resulting subnetworks are interconnected by transmission lines. The effectiveness of the proposed methodology is demonstrated through an application example in which the transient response of a network is first simulated without partitions, using the high resolution required by the transient phenomenon. Then, the same simulation is performed, but this time with the network divided into two partitions, using the same integration step for both subnetworks. Finally, the two subnetworks are simulated with different integration steps, according to the dynamics of each. The comparison of results and computation times from these three simulations confirms that transient simulations in large networks can be accelerated without compromising the accuracy of the results.

Objetives

Correctly simulate transient state using line models with frequency dependence using an electrical network with two or more modules (subsystems), using multirate techniques, that is, different integration steps for each subsystem. However, for the purposes of exemplifying the methodology, the exchange of information and the sequence of operations, the Bergeron model with losses is used.

Methodology

Methodology based on Gabriel Kron's diacoptic technique to simulate an electrical network

It consists of dividing an electrical network into subnetworks that are decoupled in time from each other.

To carry out the division of a network, it is assumed that the resulting subnetworks are joined with transmission lines.

The effectiveness of the methodology is demonstrated through an application in which the transient response is simulated without partitioning and with the network divided into two partitions.

Contributions

A methodology is presented to simulate a network separated into blocks.

It is shown that there can be reconfigurations in the interconnection of the blocks without the need to recalculate the nodal admittance matrices.

The separation, as proposed, is suitable for simulating each block with a different processor and a specific time step.

The need for a filtering stage is shown..

Bergeron, EMTP, Multirate

Resumen

En este artículo se describe una metodología basada en la técnica de diacópticas de Gabriel Kron para simular eficientemente una red eléctrica. La metodología consiste en la división de una red eléctrica grande en subredes que estén desacopladas en tiempo entre sí. Para efectuar la división de una red aquí se supone que las subredes resultantes se unen entre sí mediante líneas de transmisión. La efectividad de la metodología propuesta se demuestra a través de un ejemplo de aplicación en el cual la respuesta transitoria de una red se simula primero sin particiones y con la alta resolución requerida por el fenómeno transitorio. Después, la misma simulación es efectuada, pero ahora con la red dividida en dos particiones y utilizando el mismo paso de integración para ambas subredes. Finalmente, las dos subredes se simulan con diferentes pasos de integración, de acuerdo con la dinámica de cada una de ellas. La comparación entre resultados y de tiempos de cómputo de estas tres simulaciones confirma que las simulaciones de transitorios en redes de gran tamaño pueden acelerarse sin comprometer la precisión de los resultados.

Objetivos

Simular correctamente estado transitorio utilizando de modelos de línea con dependencia frecuencial utilizando una red electrica con dos o mas modulos (subsistemas), utilizando tecnicas de multitasa, es decir, diferentes paso de integración para cada subsistema. Sin embargo, para efectos de ejemplificar la metodología, el intercambio de información y la secuencia de operaciones se utiliza el modelo de Bergeron con pérdidas.

Metodología

Metodología basada en la técnica de diacópticas de Gabriel Kron para simular una red eléctrica

Consiste en la división de una red eléctrica en subredes que estén desacopladas en tiempo entre sí .

Para efectuar la división de una red se supone que las subredes resultantes se unen con líneas de transmisión.

La efectividad de la metodología se demuestra a través de una aplicación en el cual la respuesta transitoria se simula sin particion y con la red dividida en dos partes.

Contribuciones

Se presenta una metodología para simular una red separada en bloques.

Se muestra que puede haber reconfiguraciones en la inter-conexión de los bloques sin necesidad de recalcular las matrices de admitancias nodales.

La separación, tal como se propone, es adecuada para simular cada bloque con un procesador diferente y un paso de tiempo específico.

Se muestra la necesidad de una etapa de filtrado.

Bergeron, EMTP, Multitasa

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Introduction

In recent years, electrical power systems have shown a sustained increase in the complexity of their analysis processes. This is a consequence of several factors, among which stands out the constant increase in the dimensions of the systems due to the inclusion of new generating stations, substations, etc.; this makes the simulation of such systems more and more demanding from the computational point of view. In addition, the models used to represent the elements of a network add considerable computational and computational memory requirements. All this, added to the need to offer better quality services, means that the simulation programs traditionally used in the study of various phenomena and events involved in the operation of these systems require the implementation of new technological platforms that allow obtaining results at a higher speed. In this context, real-time simulation stands out in particular.

In most cases, a disturbance of a large electrical network only causes a small part of it to enter into fast dynamic operation, while the majority of the network will remain in a slow dynamic state. The difference in response time makes it possible to split the network and simulate each of the resulting blocks with different time steps. Thus, it is convenient to use large integration steps for subnetworks with slow dynamics, while small integration steps are reserved for subnetworks operating with fast dynamics. This technique, which is known as multirate, provides large increases in the computational efficiency of dynamic simulations; however, the state variables that are exchanged between subnetwork models running with different integration steps must be conditioned. Signals coming from a submodule with fast dynamics, going to one with slower dynamics, must first be passed through a low-pass filter and then decimated.

This is in order to avoid aliasing errors. On the other hand, signals coming from a submodule with slow dynamics, and going to one with faster dynamics, must first be interpolated and then passed through a low-pass filter that eliminates errors due to spurious spectral components produced by the interpolation.

Historical background

In the 1950s, in order to simulate large networks, Gabriel Kron developed a network partitioning technique that he called Diacoptics (Kron G. 1-7). However, the use of this technique did not become universal, and it was not until the 1970s when Happ et. al. took up the development of G. Kron for the solution and analysis of power systems (Happ, H. H.).

In 1975, Ho et. al. published a paper on Modified Nodal Analysis (MNA) (Chung-Wen H. et.al.). MNA separates the solution of a network into nodal and branch equations, and although the authors do not relate their work to the diacoptic techniques, the equations resulting from MNA are the same as those resulting from G. Kron's techniques.

In the 1990s, in the search to increase the simulation speed, A. Semlyen presents a procedure to calculate electromagnetic transients using two or more time steps (Semlyen, A. & De Leon, F.). He makes a distinction to fast buses, which he simulates with a smaller time step than the rest of the network. He proposes the coupling of variables through a line-bus interface based on traveling waves and implements the interface by interpolating the incident wave and smoothing the reflected wave. In turn, J. R. Martí extends the ideas of diacoptic techniques in the MATE (Multi Area Thevenin Equivalent) concept, which subdivides the system into independent sub-networks, except for the links that unite them (Martí, J. R. et.al. (1)).

Proposed methodology

The proposed method consists of the application of G. Kron's diacoptic techniques (Kron G. 1-7) to separate a network into subsystems interconnected by transmission lines. The models of the network elements are those used in EMTP; however, this method differs from the traditional methodology used in EMTP in that when doing the network separation, each subsystem is resolved as if the tie lines did not exist, and then the voltages of the subsystems are updated using information from the existing interconnections.

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The modeling of transmission lines in time domain is traditionally done with two-port EMTP type models, such as the Bergeron model (Dommel, H. W.), the J. Marti model (Marti, J. R. (3)), the universal model (Morched, A. et.al.) or the model based on the method of characteristics (Naredo J. L. et.al. (1)); all models have in common the schematic form. Figure 1 shows Bergeron's model, as used in EMTP, where it is illustrated for a line connected between nodes k and m. In this figure, Ikm and Imk are the outgoing currents of those nodes, hkm and hmk are the associated history currents, Vm and Vk are the voltages at the nodes and ZC is the characteristic impedance of the line (Dommel, H. W.). Additional elements that interconnect in a network, such as inductance, capacitance and resistance, have similar models (Dommel, H. W.).

Box 1

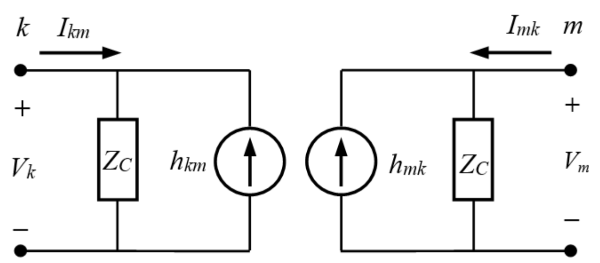

Figure 1
Diagram of the solution of the line with the Bergeron model
Source: Own elaboration

According to the schematic in figure 1, it can be seen that the lines decouple the network, so that subsystems can be formed in a natural way separated by transmission lines. This allows the parallel execution of the network, but with the following limitation: if you want to make a change during the simulation in the network topology by inserting or removing lines between two subsystems, you need to modify the nodal admittance matrix, which increases the solution time considerably. The method proposed here, in addition to the time reduction by simulation using subsystems, solves the dynamic reconfiguration problem satisfactorily.

The network in figure 2 is used to derive the method. The separation of the network is done in the line from node 2 to node 3; figure 3 shows how the partitioned network looks like, where it is also observed the reassignment in the numbering of the nodes as if each subsystem was independent.

Box 2

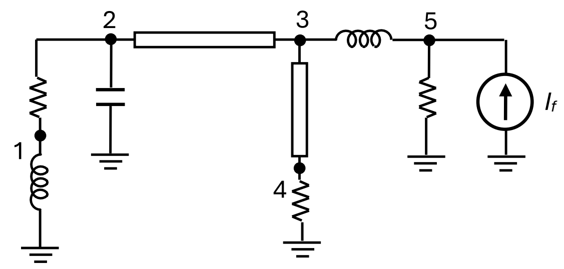

Figure 2
Test network
Source: Own elaboration

Figure 3 shows that, regardless of the number of interconnections between subsystems, the nodal admittance matrix of each subsystem does not change; in this way, the links between subsystems can be reconfigured without changing the equations that give solutions to the internal voltages of each subsystem; thus, only the updates due to the interconnections between them are modified. The derivation of the proposed method is presented in detail below.

Box 3

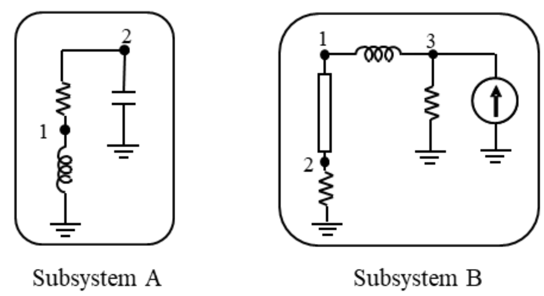

Figure 3
Network separation scheme in Figure 2.
Own figure

The nodal equations of each subsystem as an independent network are expressed as follows:

$$\begin{aligned}[\mathbf{A}][\mathbf{V_A}]&=[\mathbf{H_A}]\\ [\mathbf{B}][\mathbf{V_B}]&=[\mathbf{H_B}],\end{aligned} \quad [1]$$

where y are the nodal admittance matrices of each sub-network, y are the nodal voltage vectors, and y are vectors containing the sources of each network and the current histories due to the solution method (Dommel, H. W.).

If the set of equations (1) is grouped into a single matrix system, the following is obtained.

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$$\begin{bmatrix} \mathbf{A} & \mathbf{0} \\ \mathbf{0} & \mathbf{B} \end{bmatrix} \begin{bmatrix} \mathbf{V_A} \\ \mathbf{V_B} \end{bmatrix} = \begin{bmatrix} \mathbf{H_A} \\ \mathbf{H_B} \end{bmatrix}, \quad [2]$$

If the submatrices are expanded according to figure 3, the following system of equations is obtained:

$$\begin{bmatrix} Y_{A,11} & Y_{A,12} & 0 & 0 & 0 \\ Y_{A,21} & Y_{A,22} & 0 & 0 & 0 \\ 0 & 0 & Y_{B,11} & Y_{B,12} & Y_{B,13} \\ 0 & 0 & Y_{B,21} & Y_{B,22} & Y_{B,23} \\ 0 & 0 & Y_{B,31} & Y_{B,32} & Y_{B,33} \end{bmatrix} \begin{bmatrix} v_{A1} \\ v_{A2} \\ v_{B1} \\ v_{B2} \\ v_{B3} \end{bmatrix} = \begin{bmatrix} H_{A1} \\ H_{A2} \\ H_{B1} \\ H_{B2} \\ H_{B3} \end{bmatrix}, \quad [3]$$

In equation (3) and thereafter, the notation used is as follows: Y is admittance, the subscripts A, B, and the numbering designate the module or block to which a parameter belongs and specifically the nodes to which it is associated. This equation clearly shows how up to this point the interconnection line has not been taken into account in the construction of the nodal admittance matrix.

In order to take the tie line into account without modifying the nodal admittance matrix, it is modelled as outgoing current sources from the interconnection nodes, as can be seen in Figure 4. In this figure and in the following, the subscripts L1 indicate relationship to tie line 1; the subscripts AB and BA indicate that the current goes from subsystem A to B and vice versa; ZL1 is the characteristic impedance of tie line 1.

Box 4

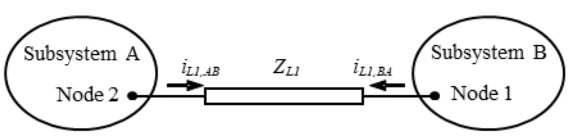

Figure 4
Interconnection diagram between subsystems

Source: Own elaboration

Thus, adding the junction line currents, $iL1_{,AB}$ and $iL1_{,BA}$, from equation (3) gives the new system of equations.

$$\begin{bmatrix} Y_{A,11} & Y_{A,12} & 0 & 0 & 0 & 0 & 0 \\ Y_{A,21} & Y_{A,22} & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & Y_{B,11} & Y_{B,12} & Y_{B,13} & 0 & 1 \\ 0 & 0 & Y_{B,21} & Y_{B,22} & Y_{B,23} & 0 & 0 \\ 0 & 0 & Y_{B,31} & Y_{B,32} & Y_{B,33} & 0 & 0 \end{bmatrix} \begin{bmatrix} v_{A1} \\ v_{A2} \\ v_{B1} \\ v_{B2} \\ v_{B3} \\ i_{L1,AB} \\ i_{L1,BA} \end{bmatrix} = \begin{bmatrix} H_{A1} \\ H_{A2} \\ H_{B1} \\ H_{B2} \\ H_{B3} \end{bmatrix}, \quad [4]$$

The system of equations given by (4) is underdetermined, so to form a system of equations with a unique solution we use the equations of the connecting line, which are:

$$i_{L1,AB}(t) = \frac{1}{Z_{L1}} v_{A2}(t) + h_{L1,AB}(t), \quad [5a]$$

$$i_{L1,BA}(t) = \frac{1}{Z_{L1}} v_{B1}(t) + h_{L1,BA}(t), \quad [5b]$$

Where $h_{L1,AB}$ y $h_{L1,BA}$ are currents of history (Dommel, H. W.).

In order to incorporate equations (5) into (4), they are first multiplied by the characteristic impedance of the line, and after an algebraic rearrangement we obtain

$$v_{A2}(t) - Z_{L1} i_{L1,AB}(t) = H_{L1,AB}(t), \quad [6a]$$

$$v_{B1}(t) - Z_{L1} i_{L1,BA}(t) = H_{L1,BA}(t), \quad [6b]$$

where the terms H_{L1} are history voltages, which are given by the following equations for a time t and a travel time of the line τ:

$$H_{L1,AB}(t) = v_{B1}(t-\tau) + Z_{L1} i_{L1,BA}(t-\tau), \quad [7a]$$

$$H_{L1,BA}(t) = v_{A2}(t-\tau) - Z_{L1} i_{L1,AB}(t-\tau) \quad [7b]$$

Equations (6) are integrated into the matrix system given by (4) to obtain

$$\begin{bmatrix} Y_{A,11} & Y_{A,12} & 0 & 0 & 0 & 0 & 0 \\ Y_{A,21} & Y_{A,22} & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & Y_{B,11} & Y_{B,12} & Y_{B,13} & 0 & 1 \\ 0 & 0 & Y_{B,21} & Y_{B,22} & Y_{B,23} & 0 & 0 \\ 0 & 0 & Y_{B,31} & Y_{B,32} & Y_{B,33} & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & -Z_{L1} & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & -Z_{L1} \end{bmatrix} \begin{bmatrix} v_{A1} \\ v_{A2} \\ v_{B1} \\ v_{B2} \\ v_{B3} \\ i_{L1,AB} \\ i_{L1,BA} \end{bmatrix} = \begin{bmatrix} H_{A1} \\ H_{A2} \\ H_{B1} \\ H_{B2} \\ H_{B3} \\ H_{L1,AB} \\ H_{L1,BA} \end{bmatrix}, \quad [8]$$

A matrix partition is made in equation (8), but the following matrices are assigned first:

$$\mathbf{U_B} = \begin{bmatrix} 0 & 1 \\ 0 & 0 \\ 0 & 0 \end{bmatrix} \quad [9a]$$

$$\mathbf{Z_L} = \begin{bmatrix} -Z_{L1} & 0 \\ 0 & -Z_{L1} \end{bmatrix} \quad [9b]$$

$$\mathbf{I_L} = \begin{bmatrix} i_{L1,AB} \\ i_{L1,BA} \end{bmatrix} \quad [9c]$$

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$$\mathbf{H_A} = \begin{bmatrix} H_{A1} \\ H_{A2} \end{bmatrix}, \mathbf{H_B} = \begin{bmatrix} H_{B1} \\ H_{B2} \\ H_{B3} \end{bmatrix}, \mathbf{H_L} = \begin{bmatrix} H_{L1,AB} \\ H_{L1,BA} \end{bmatrix} \quad [9d]$$

Using the matrix notation given by (9), we obtain in compact form

$$\begin{bmatrix} \mathbf{A} & \mathbf{0} & \mathbf{U_A} \\ \mathbf{0} & \mathbf{B} & \mathbf{U_B} \\ \mathbf{U_A^T} & \mathbf{U_B^T} & \mathbf{Z_L} \end{bmatrix} \begin{bmatrix} \mathbf{V_A} \\ \mathbf{V_B} \\ \mathbf{I_L} \end{bmatrix} = \begin{bmatrix} \mathbf{H_A} \\ \mathbf{H_B} \\ \mathbf{H_L} \end{bmatrix} \quad [10]$$

If we pre-multiply the system of equations (10) by

$$\begin{bmatrix} \mathbf{A}^{-1} & 0 & 0 \\ 0 & \mathbf{B}^{-1} & 0 \\ 0 & 0 & \mathbf{U} \end{bmatrix}, \quad [11]$$

with equal to a unitary matrix of the corresponding dimension, we get

$$\begin{bmatrix} \mathbf{U} & 0 & \mathbf{A}^{-1}\mathbf{U_A} \\ 0 & \mathbf{U} & \mathbf{B}^{-1}\mathbf{U_B} \\ \mathbf{U_A^T} & \mathbf{U_B^T} & \mathbf{Z_L} \end{bmatrix} \begin{bmatrix} \mathbf{V_A} \\ \mathbf{V_B} \\ \mathbf{I_L} \end{bmatrix} = \begin{bmatrix} \mathbf{A}^{-1}\mathbf{H_A} \\ \mathbf{B}^{-1}\mathbf{H_B} \\ \mathbf{H_L} \end{bmatrix} \quad [12]$$

From the system of equations (12) we extract and , which are given as follows

$$\mathbf{V_A} = \mathbf{A}^{-1}\mathbf{H_A} - \mathbf{A}^{-1}\mathbf{U_A}\mathbf{I_L} \quad [13a]$$

$$\mathbf{V_B} = \mathbf{B}^{-1}\mathbf{H}_B - \mathbf{B}^{-1}\mathbf{U_B}\mathbf{I_L} \quad [13b]$$

A comparison of the first term on the right-hand side of equation (13) with the solution of equation (1) shows that they are equivalent and relate to the solution of each subsystem independently. Thus, if the vectors E are defined as

$$\mathbf{E_A} = \mathbf{A}^{-1}\mathbf{H_A}, \quad [14a]$$

$$\mathbf{E_B} = \mathbf{B}^{-1}\mathbf{H}_B, \quad [14b]$$

then equation (13) can be written in the following way:

$$\mathbf{V_A} = \mathbf{E_A} - \mathbf{A}^{-1}\mathbf{U_A}\mathbf{I_L} \quad [15a]$$

$$\mathbf{V_B} = \mathbf{E_B} - \mathbf{B}^{-1}\mathbf{U_B}\mathbf{I_L} \quad [15b]$$

Equations (15) can be interpreted as follows:

1. First, the nodal voltages of the two sub-networks are calculated separately.

2. With the current flowing through the tie line, the nodal voltages are modified to obtain the actual voltage of the interconnected subsystems.

Since the calculation of the nodal voltages of the complete network requires the current flowing through the tie line, from the system of equations given by (12) we obtain:

$$\mathbf{I_L} = \mathbf{Z_L}^{-1}\left[\mathbf{H_L} - \mathbf{U_A^T}\mathbf{V_A} - \mathbf{U_B^T}\mathbf{V_B}\right] \quad [16a]$$

Substitute equations (15) into (16a) and get

$$\begin{aligned} \mathbf{I_L} &= \mathbf{Z_L}^{-1}\mathbf{H_L} - \mathbf{Z_L}^{-1}\mathbf{U_A^T}\left(\mathbf{E_A} - \mathbf{A}^{-1}\mathbf{U_A}\mathbf{I_L}\right) \\ &\quad - \mathbf{Z_L}^{-1}\mathbf{U_B^T}\left(\mathbf{E_B} - \mathbf{B}^{-1}\mathbf{U_B}\mathbf{I_L}\right) \end{aligned} \quad [16b]$$

After some algebraic manipulations and the introduction of the definition of the constant as

$$\mathbf{K} = \left[\mathbf{U} - \mathbf{Z_L}^{-1}\left(\mathbf{U_A^T}\mathbf{A}^{-1}\mathbf{U_A} + \mathbf{U_B^T}\mathbf{B}^{-1}\mathbf{U_B}\right)\right]^{-1}\mathbf{Z_L}^{-1}, \quad [17]$$

the expression is arrived at as follows,

$$\mathbf{I_L} = \mathbf{K}\left(\mathbf{H_L} - \mathbf{U_A^T}\mathbf{E_A} - \mathbf{U_B^T}\mathbf{E_B}\right), \quad [18]$$

where the term is a 2x2 diagonal matrix and the term in parentheses, in extended form, is

$$\mathbf{H_L} - \mathbf{U_A^T}\mathbf{E_A} - \mathbf{U_B^T}\mathbf{E_B} = \begin{bmatrix} H_{L1,AB} \\ H_{L1,BA} \end{bmatrix} - \begin{bmatrix} E_{A2} \\ 0 \end{bmatrix} - \begin{bmatrix} 0 \\ E_{B1} \end{bmatrix}. \quad [19]$$

Substituting (17) and (19) into (18) we get

$$\begin{bmatrix} I_{L1,AB} \\ I_{L1,BA} \end{bmatrix} = \begin{bmatrix} \mathrm{K}_{11} & 0 \\ 0 & \mathrm{K}_{22} \end{bmatrix} \begin{bmatrix} H_{L1,AB} - E_{A2} \\ H_{L1,BA} - E_{B1} \end{bmatrix}. \quad [20]$$

Thus, we finally arrive at the current equations in the link line

$$i_{L1,AB}(t) = \mathrm{K}_{11}\left(H_{L1,AB}(t) - E_{A2}(t)\right) \quad [20a]$$

$$i_{L1,BA}(t) = \mathrm{K}_{22}\left(H_{L1,BA}(t) - E_{B1}(t)\right) \quad [20b]$$

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Equation (20) shows that the current at each end of the line depends on the internal voltage of the networks at the junction point as if the interconnection did not exist and on the history voltage of the junction line.

This leaves the equations needed to simulate a network using parallel processing. The flowchart indicating the order and operations required for the network simulation is presented below.

Multirate transients

In an electrical network, not all elements respond at the same rate; for example, there are occasions when two regions can be distinguished: one region with a fast disturbance and another that operates close to steady state. It is in such situations that the network can be conveniently divided for analysis into two regions; such is the case of the test network illustrated in figure 2, whose separation by the proposed method is shown in figure 3. Once the network is separated and the sectors with fast and slow dynamics are identified, simulation with different time steps for each sector becomes possible.

The interconnection between the subsystems is done through the transmission line link, and specifically through the voltage histories that in the proposed method are named $HL1_{,AB}$ and $HL1_{,BA}$. The former transmits the necessary information from the fast system to the slow system and the latter provides this information from the slow dynamic system to the fast dynamic system. As the systems have different sampling rates, the information exchanged between subsystems must be conditioned; how this is done is described below.

Multirate theory

The process of converting a signal of a given rate to a different rate is called sampling rate conversion.

Systems employing multiple sampling rates in digital signal processing are called multi-rate digital processing systems (Naredo, J. L. et.al. (2)) and (Vaidyanathan, P. P.). Sample rate conversion in the digital domain is performed under the concept of interpolation and decimation.

Decimation. Decimation is characterised by the input-output relationship

$$y_D(n) = x(Mn) \quad [22]$$

This equation, (22), indicates that the output y_D at time n is equal to the input x at time Mn. As a consequence, only input samples with sample numbers equal to a multiple of M are retained. When the input $x(n)$ is undersampled by an integer factor M, the sampling frequency is reduced by selecting every M values of $x(n)$, so the resulting signal is an aliased version of $x(n)$, with an overlapping frequency, where is the maximum frequency of the input signal $x(n)$. To avoid aliasing, the bandwidth of $x(n)$ must first be reduced to a maximum frequency, or equivalently, to . For this task, the sequence $x(n)$ is passed through a low pass filter to remove the spectrum of $x(n)$, , in the range.

Interpolation. An interpolator is characterised by the input-output relation

$$y_I(n) = \begin{cases} x(n/L) & \text{Si } n \text{ es un múltiplo de } L \\ 0 & \text{En otro caso} \end{cases} . \quad [23]$$

This means that the interpolated output is obtained by inserting L-1 zero-valued samples between adjacent samples of the input $x(n)$. This type of interpolation preserves the spectral shape of the signal $x(n)$. When L-1 new samples are interpolated between successive values of the signal, an increase in the sampling frequency is achieved; this results in a signal whose spectrum is a periodic and overlapping repetition L times of the spectrum, which belongs to the input signal . Since the frequency components of in the range are unique, the images of above must be removed by passing the sequence y_I(n) through a low-pass filter. Figure 5 shows a one-channel multirate system, showing the decimation and interpolation processes with their respective filters as described above.

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Box 5

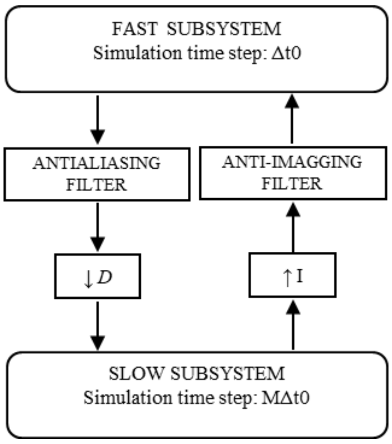

Figure 5
Single-channel multirate system
Source: Own elaboration

Application of the methodology

The proposed method is applied to the test network in figure 2 to perform a qualitative and quantitative analysis on the behaviour of the nodal voltages over time. A detailed description of this network is given below, followed by a description of the stages of this work.

Description of the test system

Table 1 presents the data corresponding to the elements of the test network, as well as their connectivity. The line model is Bergeron with losses concentrated at the ends. The characteristic impedance of the lines is 450Ω and their resistance is 1Ω at each end. In order to maximise the transient state of the network, a cosine function of unit amplitude is used for the current source (at energisation time, t=0, the maximum value of the source is presented).

Box 6

Table 1
Connectivity and test case parameters

Source node	Node destination	Element	Value
1	0	Inductance	25μH
1	2	Resistance	1Ω
2	0	Capacitance	1μF
2	3	Line	150km
3	4	Line	210km
3	5	Inductance	25mH
4	0	Resistance	1Ω
5	0	Resistance	1Ω

The base simulation has a time step Δt0=0.41667μs, which corresponds to a travel time of 125m at the speed of light. In all simulation cases, the observation time is 30ms, equivalent to almost 2 cycles of 60 Hz.

Description of the stages

In stage 1, the network simulations correspond to the original system (see figure 2), and to the split network as shown in figure 6. In this stage it is satisfied that N=M, i.e. the time step in both blocks is the same.

Box 7

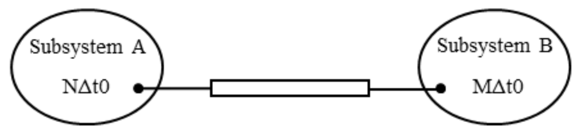

Figure 6
Simulation scheme for the network partitioned into 2 blocks
Source: Own elaboration

The second stage concerns the multi-rate simulations, where the scheme in figure 7 is used with N=1, meaning that the base time step is maintained in subsystem A.

Both stages are described in more detail in the following subsections. It should be noted that the error plots included therein refer to the absolute value of the difference between the voltage of a certain node of the base simulation and that of the simulation in question, referenced to the corresponding peak voltage of the base simulation, in percent.

Step 1

Simulations of the original system (figure 2) and the partitioned system are performed with time step variations: from the base_, Δt0, to 300Δt0; note that the same time step is used in both blocks. In this part, it is first verified that the separation of a network into blocks yields the same results in the simulation as the originating network, which is true regardless of the time step used. Subsequently, an analysis of the simulation runtimes of the two system configurations is performed: the original system and the system split into two blocks. Table 2 shows the results of the simulation run times for each case. Columns four and five show the reductions, in percent, in the simulation time of the original and block networks, when taking as a reference the execution time of the base system (with Δt0).

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Box 8

Table 2

Simulation times

M	Simulation time (pu)		Reduction of simulation time (%)	
	Red original	Red en bloques	Red original	Red en bloques
1	1	0.233037	0.0000	76.6962
2	0.242621	0.057707	75.7379	94.2292
4	0.059530	0.014662	94.0470	98.5338
6	0.026320	0.006491	97.3679	99.3509
8	0.014621	0.003834	98.5379	99.6165
10	0.009150	0.002320	99.0850	99.7679
12	0.006194	0.001496	99.3806	99.8503
20	0.002083	0.000516	99.7916	99.9484
30	0.000963	0.000239	99.9036	99.9761
40	0.000501	0.000155	99.9498	99.9844
50	0.000316	0.000060	99.9683	99.9940
60	0.000211	0.000046	99.9789	99.9954
100	0.000057	0.000025	99.9942	99.9975
120	0.000031	0.000020	99.9968	99.9979
150	0.000023	0.000018	99.9976	99.9981
200	0.000016	0.000013	99.9983	99.9987
300	0.000009	0.000013	99.9989	99.9991

Table 2 clearly illustrates how from a certain time increment onwards, the simulation times of the block network and the original network are very similar; this is because the communication time between blocks within the observation period for small time steps is irrelevant, but when they increase (M increases) it becomes important.

Figure 7 shows graphically how the reduction of the simulation time of the block network approaches the reduction of the original network as the time step increases; in other words, the block network starts to require the same simulation time as the full network.

Box 9

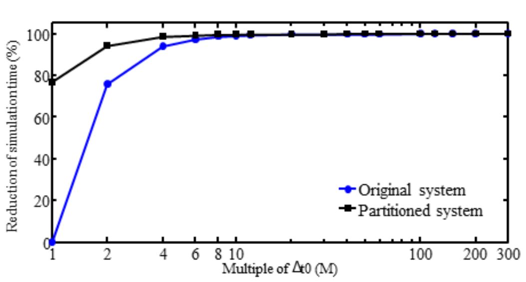

Figure 7

Reduction of simulation time compared to the base simulation

Source: Own elaboration

Regarding the errors related to the time step used, figure 8 shows the maximum errors obtained over the whole time. The error at node 5 is omitted as it is negligible compared to the rest, due to the fact that the source is connected to it.

Figure 9 presents the steady-state errors in the voltages. This figure shows how the errors are substantially reduced to less than 0.1%, except for node 1, where an inductance is connected.

Figure 10 presents the behaviour of the error from the beginning of the simulation until it stabilises; the errors of all simulations (all M) are presented. Only node 1 is presented, as the behaviour is similar for the rest of the nodes. It can be seen in this figure the gradual decrease of the error, independently of the time step. For this purpose, a close-up of the first oscillation and the steady state is presented.

Box 10

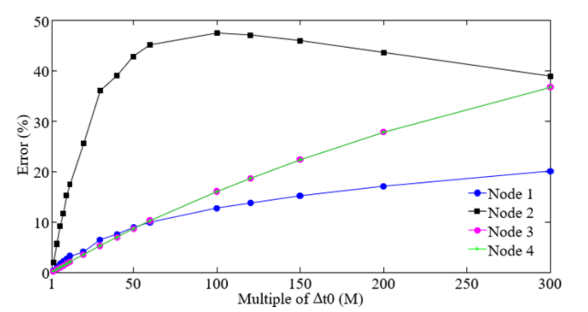

Figure 8

Maximum errors in nodal voltages

Source: Own elaboration

Box 11

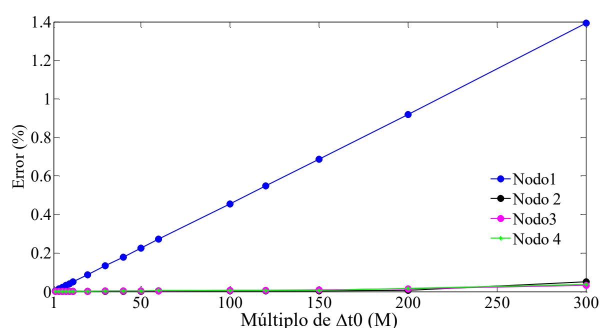

Figure 9

Minimum errors (during steady state) in nodal voltages

Source: Own elaboration

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Box 12

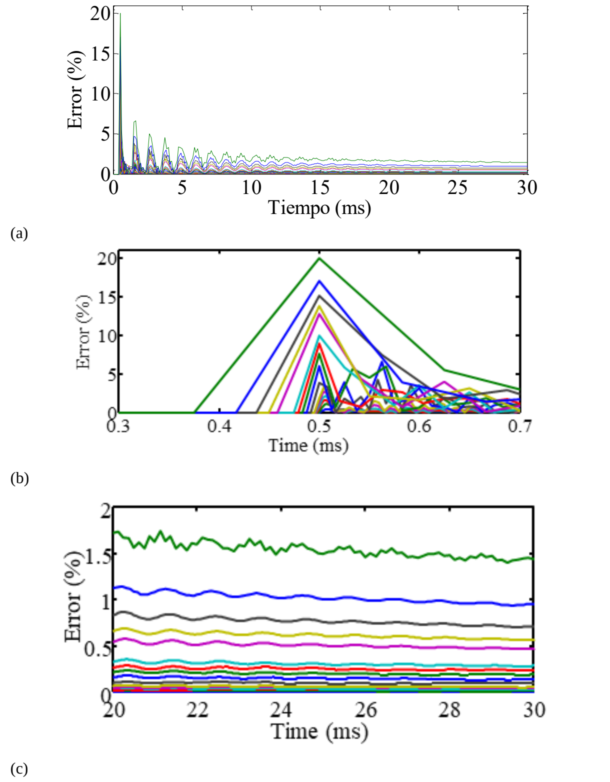


Figure 10

Voltage error throughout the simulation at node 1. (a) Full simulation. (b) Approach to maximum error. (c) Approach to minimum error

Source: Own elaboration

At this stage, it is concluded that there comes a point where the time savings due to the use of several processors is not significant when simulating a block-partitioned power system.

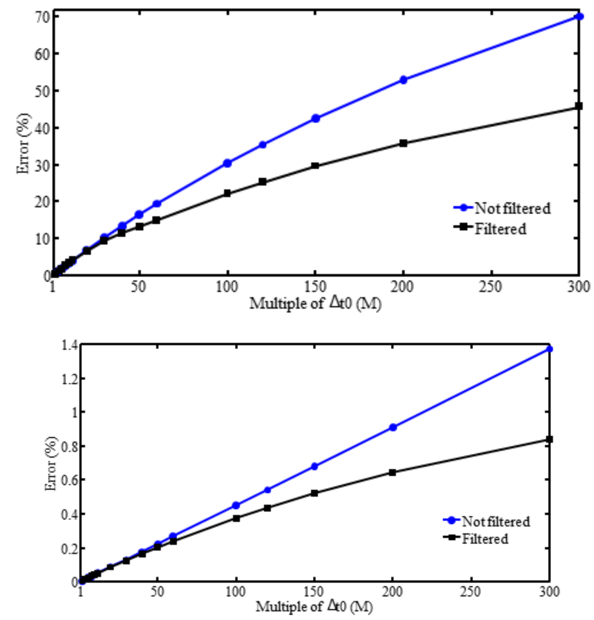
Also, according to the results obtained, it can be said that the use of relatively large time increments can be adequate to simulate steady state, although it yields large errors in transient state.

Stage 2

In this stage, the test network is simulated with multi-rate, as shown in Figure 5. In subsystem A, the base time step, Δt0, is always used, while in subsystem B, MΔt0 is used, and M is varied from 2 to 300.

The first test is to verify the influence of the filtering stage on the errors of the nodal voltages of the signals exchanged between subsystems. Figure 11 shows the maximum and minimum errors at node 1 when the filtering stage is used and when it is omitted.

Box 13



(b)

Figure 11

Errors in node 1 voltages. (a) Maximum errors. (b) Minimum errors

Source: Own elaboration

To verify the qualitative effect of the filtering stage, a comparison of the voltage waveforms at node 2 obtained when using 100Δt0 in subsystem B is shown in figure 13.

It should be noted that in this case a rectangular window is used for filtering. In figure 13 it can be seen how the filtering steps lead to a better solution from a qualitative point of view. This is why the filtering stages are incorporated and the simulations are carried out.

Box 14

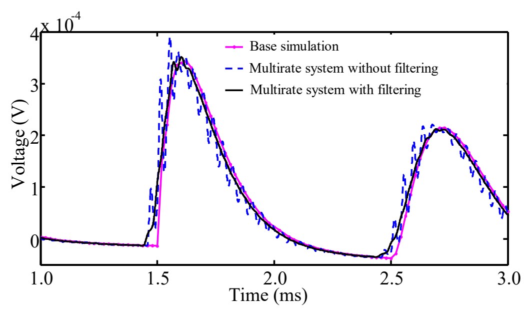


Figure 12

Voltage waveforms at node 2. Base system and multi-rate system with M = 100

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Figure 13 shows the voltage behaviour at node 2, which belongs to the fast simulation block, for three situations: base simulation (original system with Δt0), the block system (MΔt0 in both subsystems), and the multi-rate system (Δt0 in subsystem A and MΔt0 in subsystem B) with M=50. It can be seen how the simulation of the block system does not correctly reproduce the transient state of the fast subsystem, i.e. the M used is no longer adequate to simulate this subsystem.

Box 15

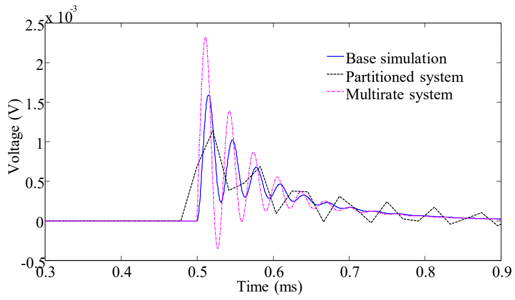

Figure 13
Node 2 voltage waveforms. Base system, block and multi-rate systems

Source: Own elaboration

If only the maximum errors are considered, in apparent form the block system yields better results than if the multiresolution technique is used, as can be seen by comparing figure 14 with figure 8.

However, figure 14 makes it clear that the waveform using multiresolution is more appropriate, as it looks more like the base simulation, the accumulated error during the simulation is lower.

In relation to the steady state, which is where the minimum errors are obtained, the comparison between figures 9 and 15 shows how the use of multiresolution provides a lower error compared to the use of the same time step in both subsystems, which is an expected result.

Box 16

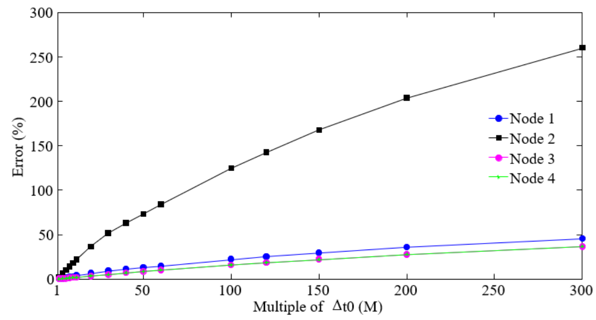

Figure 14
Maximum errors in nodal voltages. Own figure

Box 17

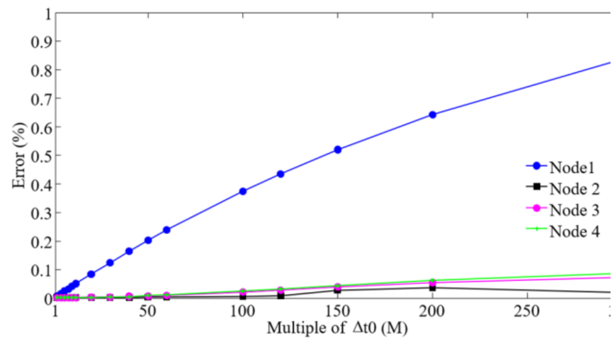

Figure 15
Minimum errors in nodal voltages

Source: Own elaboration

On the other hand, figure 17 shows the results of the reduction in simulation time when going from the base system to the multi-rate system. It can be seen that after a certain time step, the execution time of the simulations is no longer reduced; this is due to the fact that the time taken to exchange information becomes more significant as the simulation time decreases, which in turn is a consequence of increasing the time step in the slow subsystem. Of course, this specific behaviour is specific to this system and its partitioning set-up.

Galván-Sánchez, Verónica Adriana, Gutiérrez-Robles, José Alberto, Bañuelos-Cabral, Eduardo Salvador and López de Alba, Carlos Alberto. [2024]. Simulation of power grids using multirate methods. Journal Computational Simulation. 8[19]-1-13: e20819113.
DOI: https://doi.org/10.35429/JCS.2024.8.19.2.13

Box 18

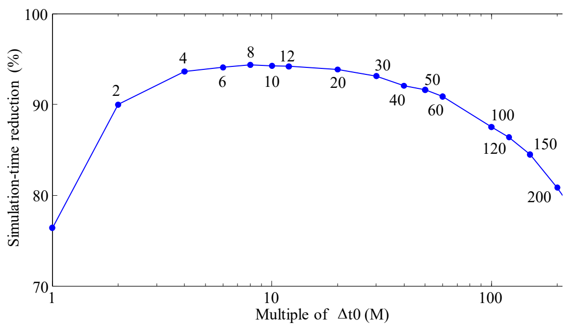

Figure 16
Reduction of simulation time by increasing the time step in subsystem B
Source: Own elaboration

From figure 16 it can also be seen that multirate simulations with M greater than 8 are not useful, since from this M onwards the simulation time does not reduce any further, while the errors continue to increase, as can be seen in figures 14 and 15.

Conclusions

This paper presents a methodology for simulating a network separated into blocks. The methodology shows that there can be reconfigurations in the interconnection of the blocks without the need to recalculate the nodal admittance matrices. The separation, as proposed, is suitable for simulating each block with a different processor and a specific time step; the work shows in detail the equations that model each block and the interconnections between them. To clarify the process, a flow diagram is provided, useful to reproduce the simulations.

To correctly simulate transient state it is necessary to use line models with frequency dependence; however, for the purpose of exemplifying the methodology, the exchange of information and the sequence of operations, the Bergeron model with losses is used.

Furthermore, this work shows the need for a filtering stage and how not just any time step can be used in the slow system, since at a certain point in time, in addition to the increase of the error in the network parameters, the time in which the system is simulated also increases.

It should be clear that the appropriate time steps to simulate each subsystem as well as the way to perform the block separations are specific to each network; this has been extensively studied (Linares, L. R. & Martí, J. R.) and (Moreira, F. A. (3) & Martí, J. R.). and is not the subject of this work.

Conflict of interest

The authors declare that they have no conflicts of interest. They have no known competing financial interests or personal relationships that might have appeared to influence the article reported in this paper.

Authors' contribution

Galván-Sánchez, V. A.: Wrote the article.

Gutiérrez-Robles, J. A.: Development of the simulations and elaboration of the figures in the article.

Bañuelos-Cabral, E. S.: Review, generation and selection of the examples and/or results presented in the article.

López-DeAlba, C. A.: Revision of the content and formatting of the article.

Availability of data and materials

All the results obtained are in the article and are freely available according to the journal's policies.

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Abbreviations

MNA Modified Nodal Analysis

EMTP Electromagnetic Transient Programme

MATE Multi-area Thevenin Equivalent

Galván-Sánchez, Verónica Adriana, Gutiérrez-Robles, José Alberto, Bañuelos-Cabral, Eduardo Salvador and López de Alba, Carlos Alberto. [2024]. Simulation of power grids using multirate methods. Journal Computational Simulation. 8[19]-1-13: e20819113.
DOI: https://doi.org/10.35429/JCS.2024.8.19.2.13

References

Background

Kron, G. (1). Un método para resolver sistemas físicos muy grandes en etapas fáciles. Proceedings of the IRE 42.4, 1954, pp. 680-686. Doi: 10.1109/JRPROC.1954.274704

Kron, G. (2). Circuito equivalente de las ecuaciones de campo de Maxwell-I. Proceedings of the IRE 32.5, 1944. Doi: 10.1109/JRPROC.1944.231021

Kron, G. (3). Un conjunto de principios para interconectar las soluciones de los sistemas físicos. Journal of Applied Physics 24.8, 1953, p. 965-980. https://doi.org/10.1063/1.1721447

Kron, G. (4). Tensorial Analysis of Integrated Transmission Systems Part I. The Six Basic Reference Frames. American Institute of Electrical Engineers, Transactions of the 70.2, 1951. Doi: 10.1109/T-AIEE.1951.5060553

Kron, G. (5). Tensorial Analysis of Integrated Transmission Systems; Part II. Off-Nominal Turn Ratios. Power Apparatus and Systems, Parte III. Transactions of the American Institute of Electrical Engineers 71.1, 1952, pp. 505-512. Doi: 10.1109/AIEEPAS.1952.4498501

Kron, G. (6). Tensorial Analysis of Integrated Transmission Systems, Part III. The Power Apparatus and Systems. Transactions of the American Institute of Electrical Engineers 71.1, 1952. Doi: 10.1109/AIEEPAS.1952.4498544

Kron, G. (7). Tensorial Analysis of Integrated Transmission Systems; Part IV. La interconexión de los sistemas de transmisión. Power Apparatus and Systems. Transactions of the American Institute of Electrical Engineers 72.2, 1953. Doi: 10.1109/AIEEPAS.1953.4498707

Happ, H. H. Diakoptics-The solution of system problems by tearing. Actas del IEEE 62.7, 1974. DOI: 10.1109/PROC.1974.9545

Fundamentals

Chung-Wen, H.; Ruehli, A. & Brennan, P. The modified nodal approach to network analysis. Circuits and Systems, IEEE Transactions on, 1975, vol. 22, no 6, pp. 504-509. DOI: 10.1109/TCS.1975.1084079

Linares, L. R. & Martí, J. R. Sub-area latency in a real time power network simulator. International Conference on Power System Transients, 1995, pp. 541-545.

Supports

Dommel, H. W. Programa de transitorios electromagnéticos: Manual de referencia. Bonneville Power Administration, 1986.

Martí, J. R. (1); Linares, L. R.; Calvino, J. & Dommel, H. W. OVNI: An Object Appoach to Real-Time Power System Simulators. Power System Technology, 1998. Actas. POWERCON'98. Conferencia internacional de 1998. Vol. 2. IEEE, 1998, pp. 977-981. **DOI:** 10.1109/ICPST.1998.729230

Martí, J. R. (2); Linares, L. R.; Hollman, J. A. & Moreira, F. A. OVNI: Integrated software/hardware solution for real-time simulation of large power systems. Actas del PSCC. Vol. 2. 2002.

Moreira, F. A. (2); Martí, J. R. & Zanetta Jr, L. C. Multirate Simulations With Simultaneous-Solution Using Direct Integration Methods in a Partioned Network Enviroment. 2006, pp. 2765-2777. DOI: 10.1109/TCSI.2006.882821

Moreira, F. A. (3) & Martí, J. R. Latency techniques for time-domain power system transients simulation. Power Systems, IEEE Transactions on 20, no. 1, 2005, pp 246-253. DOI: 10.1109/TPWRS.2004.841223

Tomim, M. A. (1); Martí, J. R.; De Rybel, T.; Wang, L. & Yao, M. MATE network tearing techniques for multiprocessor solution of large power system networks. Power and Energy Society General Meeting, 2010 IEEE. IEEE, 2010, pp. 1-6. DOI: 10.1109/PES.2010.5590110

ISSN: 2523-6865
RENIECYT-CONAHCYT: 1702902

Tomim, M. A. (2); De Rybel, T. & Martí, J. R. Extending the Multi-Area Thevenin Equivalents method for parallel solutions of bulk power systems. International Journal of Electrical Power & Energy Systems, 2013, vol. 44, no 1. https://doi.org/10.1016/j.ijepes.2012.07.037

Tomim, M. A. (3); Martí, J. R. & Wang, L. Parallel solution of large power system networks using the Multi-Area Thévenin Equivalents (MATE) algorithm. International Journal of Electrical Power & Energy Systems 31, 2009. https://doi.org/10.1016/j.ijepes.2009.02.002
Differences

Moreira, F. A. (1); Martí, J. R. & Linares, L. R. Electromagnetic transients simulation with different time steps-The latency approach . Proc. Int. Conf. Power System Transients (IPST), New Orleans, USA. 2003.

Semlyen, A. & De Leon, F. Computation of electromagnetic transients using dual or multiple time steps. Power Systems, IEEE Transactions on, 1993, vol. 8, no 3, pp. 1274-1281. DOI: 10.1109/59.260867

Vaidyanathan, P. P. Multirate digital filters, filter banks, polyphase networks, and applications: A tutorial. Actas del IEEE 78.1, 1990, pp. 56-93. DOI: 10.1109/5.52200

Venerdini, G. (2); Guidi, D.; Zini, H. C. & Rattá, G. Two-channel multirate network equivalent aimed to real-time electromagnetic transient calculation . Generation, Transmission & Distribution, IET, 2012, vol. 6, no 8, pp. 738-750. DOI: 10.1049/iet-gtd.2011.0827

Zini, H. & Ratta, G. Multirate modeling scheme for electromagnetic transients calculation. Power Delivery, IEEE Transactions on, 2004, vol. 19, no 1. DOI: 10.1109/TPWRD.2003.817745

Debates

Davidson, D. B.: «A parallel processing tutorial. Antennas and Propagation Magazine, IEEE, 1990, vol. 32, no 2, pp. 6-19. DOI: 10.1109/74.80494

Martí, J. R. (3). Accurate Modeling of Frequency Dependent Transmission Lines in Electromagnetic Transient Simulations. IEEE Trans. on PAS, vol. PAS-101, pp. 147-157, 1982. DOI: 10.1109/TPAS.1982.317332

Morched, A.; Gustavsen, B. & Tartibi, M. A universal model for accurate calculation of electromagnetic transients on overhead lines and underground cables. Power Delivery, IEEE Transactions on, 1999, vol. 14, no 3, pp. 1032-1038. DOI: 10.1109/61.772350

Naredo J. L. (1); Soudack, A. & Martí, J. R. Simulación de transitorios en líneas de transmisión con corona mediante el método de las características. Generation, Transmission and Distribution, IEE Proceedings-IET, 1995. pp. 81-87. DOI: 10.1049/ip-gtd:19951488

Naredo, J. L. (2); Mahseredjian, J., Kocar, I.; Gutiérrez-Robles, J. A. & Martinez-Velasco, J. A. Frequency Domain Aspects of Electromagnetic Transient Analysis of Power Systems. IEEE/PES Tutorial on Electromagnetic Transients in Power Systems. Solution Techniques, Applications, Simulation Tool Development, Editor: J. A. Martínez-Velasco, pp. 20-36. DOI: 10.1002/9781118694190.ch3

Venerdini, G. (1); Guidi, D.; Zini, H. C.; Rattá, G. & Arispe, J. C. G. Multirate network equivalent model for electromagnetic transient calculation in real time. Conferencia y Exposición de Transmisión y Distribución: Latinoamérica (T&D-LA), 2010 IEEE/PES. IEEE, 2010. pp. 155-162. DOI: 10.1109/TDC-LA.2010.5762876

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Article

Professional residency web system implementing artificial intelligence model

Sistema web de residencia profesional implementando modelo de inteligencia artificial

Diaz-Sarmiento, Bibiana*[a], Román-Hernández, Esteban Daniel[b], Morales-Hernández, Maricela[c] and Salinas-Hernández, Fabiola[d]

[a] Instituto Tecnológico de Oaxaca • KZU-9558-2024 • 0000-0003-4350-6311 • 820776
[b] Instituto Tecnológico de Oaxaca • LFU-0261-2024 • 0009-0001-3330-046X • 1309412
[c] Instituto Tecnológico de Oaxaca • AIE-3718-2022 • 0000-0002-3521-2041 • 731036
[d] Instituto Tecnológico de Oaxaca • LEM-8141-2024 • 0009-0000-5718-489X • 2066230

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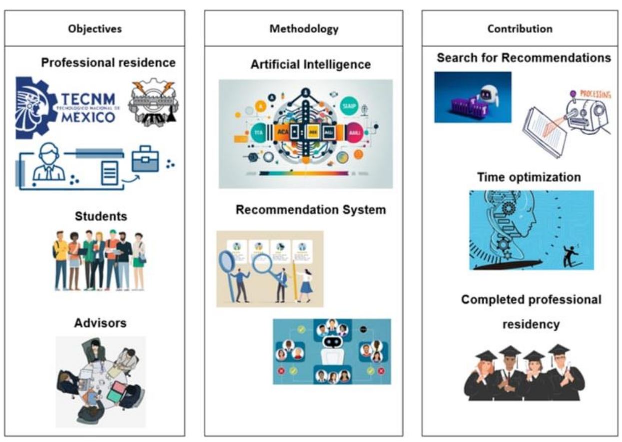
* ✉ [bibiana.diaz@itoaxaca.edu.mx]

Abstract

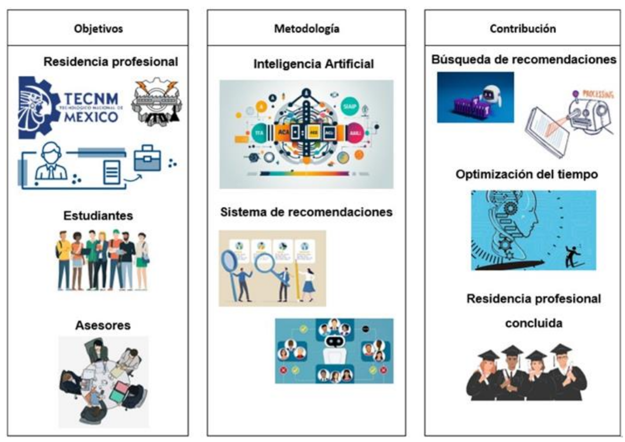
Computer Systems Engineering students at the Tecnológico Nacional de México – Instituto Tecnológico de Oaxaca take the Professional Residency subject in semesters nine or ten, which has a value of 10 credits. A project related to their area of study must be developed in a company in 4 to 6 months. To take it, it is necessary to attend different departments and carry out the corresponding process. At the Outreach Projects office, students must submit their Professional Residency preliminary project. A professor from the academy reviews this draft for authorization. Once approved, an Internal Advisor is assigned. Thanks to the Recommendation System based on Artificial Intelligence, a suggestion of teachers who could be assigned as Internal Advisors is provided, thus facilitating the selection process and ensuring better alignment between the project and the consultant's experience.



AI, Professional residence, System

Resumen

Los estudiantes de Ingeniería en Sistemas Computacionales del Tecnológico Nacional de México – Instituto Tecnológico de Oaxaca cursan la materia de Residencia Profesional en los semestres nueve o diez, la cual tiene un valor de 10 créditos. Se debe desarrollar en una empresa un proyecto relacionado con su área de estudio en 4 a 6 meses. Para cursarla, es necesario asistir a diferentes departamentos y llevar a cabo el proceso correspondiente. En la oficina de Proyectos de Vinculación, los estudiantes deben presentar su anteproyecto de Residencia Profesional. Un profesor de la academia revisa dicho anteproyecto para su autorización. Una vez aprobado, se procede a la asignación de un Asesor Interno. Gracias al Sistema de Recomendaciones basado en Inteligencia Artificial, se proporciona una sugerencia de docentes que podrían ser asignados como Asesores Internos, facilitando así el proceso de selección y asegurando una mejor alineación entre el proyecto y la experiencia del asesor.



IA, Residencia Profesional, Sistema

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Introduction

The National Technological Institute of Mexico - Technological Institute of Oaxaca, has incorporated the subject of Professional Residency into its various educational programs. This course is taken during the last semester of each program, allowing students to apply their theoretical knowledge in a real professional environment.

To start the professional residency, students attend the departments of Technology Management and Linkage, Division of Professional Studies, School Services and the Academic Department, as indicated in Process 3. Education Management - Professional Residencies Procedure, of the Quality Management System (QMS), in each department must cover the respective process.

In the academic department – Department of Systems and Computing – Liaison Office, the process for students of Computer Systems Engineering begins. Each semester (January-June and August-December) the student is asked for a preliminary project to be reviewed and authorized for Professional Residency.

This administrative task contains the following actions:

- Reception of preliminary projects from students.

- Review and authorization of the preliminary project by the Academy of Systems and Computing.

- Authorization of the application for Professional Residency by the head of the Department of Systems and Computing and/or head of the liaison office of the academic department.

- Reception of: schedule of activities, cover letter, commitment letter, acceptance letter, 1st report, 2nd report, final report, release letter.

- Delivery of the Technical Report of Professional Residency by the students.

To manage the information of the process, the Professional Residency System was carried out by implementing an Artificial Intelligence model. This system aims to implement Artificial Intelligence through a recommendation system, which will allow one or more reviewers to be suggested for a preliminary project of Professional Residency. In this way, it seeks to optimize the review selection process, ensuring a more appropriate evaluation aligned with the needs of the project.

The role of the reviewer is to carry out a thorough analysis of the document, including the problem approach, objectives, rationale, scope, limitations and schedule of activities. This analysis is carried out taking into account the experience and specialization of the reviewer or reviewers, which guarantees a critical and well-founded evaluation of the content presented.

Considering the above, the following sections are presented in this research: Methodology used, Development, Results, Acknowledgements, Financing, Conclusions and References. They cover the most relevant points in the Professional Residency Web System implementing an Artificial Intelligence model.

Methodology used

There are different software development methodologies, Maida & Pacienzia (2015) they say that the software development methodology is “an integrated set of techniques and methods that allows to approach in a homogeneous and open way each of the activities of the life cycle of a development project”.

Software development methodologies fall into two main categories: traditional methodologies and agile methodologies. Traditional methodology is one of the fundamental foundations for software development, serving as a reference for other types of methodologies.

Pressman (2022), it indicates that traditional software development methodologies are oriented by planning. They start the development of a project with a rigorous process of elicitation of requirements, prior to the stages of analysis and design. With this they try to ensure high-quality results circumscribed to a calendar.

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Navarro Cadavid, Fernández Martínez & Morales Vélez (2013), describe agile methodologies as flexible, these can be modified to fit the reality of each team and project.

Projects are highly collaborative and better adapted to change; changing requirements are an expected and desired feature, as are constant deliveries to the customer and feedback from them.

Box 1

Table 1

Traditional Methodology and Agile Methodology

Pressman, 2002	Agile Approach	Traditional approach
Organizational structure	Iterative	Lineal
Project Scale	Small and medium	Big
Customer Engagement	Register	To remove
Development model	Evolutionary Delivery	Life cycle
Customer engagement	Customers are involved from the moment work starts	Customers are involved early in the project, but not once execution has begun
Modeling preferences	Agile model promotes adaptation	The traditional model favors anticipation
Revisions and adaptations	Reviews are performed after each iteration.	Constant reviews and approvals by project leaders.

Source: Pressman 2002

Methodology by prototypes

(Gerea, 2021) The prototyping methodology is related to continuous improvement and the Deming Cycle which consists of an iterative process focused on designing, implementing, measuring and adjusting a plan. In the case of a prototype, five stages are applied in the design and implementation of an idea. These stages are:

- Definition of requirements and variables.
- Definition of tools for design and testing.
- Prototype design.
- Prototype testing.
- Analysis of results.

This methodology can be applied in the development of new businesses, web prototyping, app prototyping, among other environments.

Technology

The technologies used for the development of the Professional Residency System implementing an Artificial Intelligence model were:

- Phyton.
- Django.
- Amazon WEB Services (AWS).
- Figma.
- JavaScript (JS).
- JQUERY.
- SweetAlert2.
- HTML.
- CSS.
- Tailwind.
- Database.
- SGBD.
- Entity-relationship model.

Web architecture

In this pattern, the "Model" refers to access to the data layer, the "View" refers to the part of the system that selects what to display and how to display it, and the "Controller" implies the part of the system that decides which view to use, depending on the user input, and the "Controller" refers to the part of the system that decides which view to use, depending on the user input. accessing the model if necessary (Django 1.0).

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Box 2

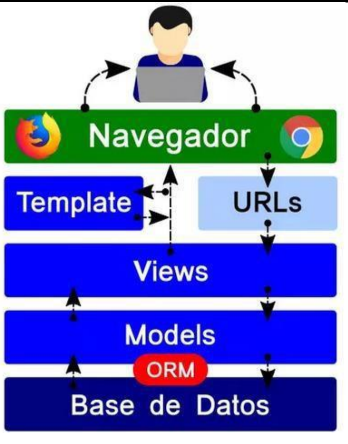

Figure 1
Design Pattern MTV

Source: Django 1.0

In practice, the MTV pattern is very similar to the MVC to such an extent that it can be said that Django is an MVC framework.

Artificial Intelligence

Artificial Intelligence is a field of science that focuses on the creation of computers and machines capable of reasoning, learn and act in ways that would normally require human intelligence, or handle data whose scale exceeds the capacity of human analysis (Russell & Norvig, 2016).

Artificial Intelligence is an extensive field covering various disciplines, including computer science, data analysis and statistics, hardware and software engineering, linguistics, neuroscience, as well as philosophy and psychology (Brachman & Levesque, 2004)

Types of intelligence

Artificial intelligence can be classified in a variety of ways, either according to the stages of development or the actions being carried out. According to Russell and Norvig (2016), this classification includes:

- Reactive machines: These are limited AI systems that only respond to different types of stimuli based on programmed rules. "They have no memory or the ability to learn from past experiences".

- Limited memory: This type of AI, which represents most modern applications, "can use past experiences to make future decisions" (Goodfellow et al., 2016).

- Theory of mind: This stage involves the ability to understand that others have beliefs, desires, and intentions that influence their behavior (Müller, 2020).

- Self-knowledge: This more advanced level of AI refers to systems that have an understanding of themselves and their own internal state, allowing them to act more autonomously and thoughtfully (Bostrom, 2014).

Recommendation Systems

Rocca (2021) notes that, in recent decades, the rise of platforms such as YouTube, Amazon, and Netflix has led to recommendation systems playing an increasingly important role in our lives. These systems are essential in multiple contexts, from e-commerce, where they suggest to buyers products that might interest them, to online advertising, which recommends content to users based on their preferences.

Today, recommendation systems are inescapable in our daily online interactions

Classification of Recommendation Systems:

According to the article "Classifying Different Types of Recommender Systems" (2015), recommendation systems are defined as tools that provide personalized recommendations to users, based on recommendations entries offered by others. These systems not only generate individualized recommendations, but also guide users to interesting options within a wide set of possibilities. Six types of recommendation systems that are relevant in the media and entertainment industry are mainly identified:

1. Collaborative recommendation system: Relies on the preferences of multiple users to make suggestions.

2. Content-based recommendation system: Use item characteristics to recommend similar ones.

3. Demographic-based recommendation system: Focuses on user demographics to personalize recommendations.

4. Recommendation system based on utilities: Considers the perceived usefulness of the items for the user.

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Diaz-Sarmiento, Bibiana, Román-Hernández, Esteban Daniel, Morales-Hernández, Maricela and Salinas-Hernández, Fabiola. [2024]. Professional residency web system implementing artificial intelligence model. Journal Computational Simulation. 8[19]-1-8: e30819108.
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5. Knowledge-based recommendation system: Uses domain-specific knowledge to make recommendations.

6. Hybrid Recommendation System: Combines multiple approaches to improve recommendation accuracy.

Development

In the Professional Residency Web System implementing an Artificial Intelligence model, the following users are identified:

- Super Admin.

- Head of the Systems and Computing Department.

- Head of the Liaison Projects Office of the Department of Systems and Computing.

- Teacher.

- Student.

One of the objectives of the Web System of Professional Residence implementing model of Artificial Intelligence is to make the intelligent decision for the assignment and monitoring of professional residency projects of the Department of Systems and Computing. Recommendations are made from the candidate teachers to advise the residency based on the characteristics identified in the preliminary project taking into account the academic profile of the teacher, his academic degrees and the area of knowledge he dominates.

Different modules were used for the development of the System:

- Student management module.

- Teacher management modules.

- Module of the head of the office of systems and computing linkage projects.

- Module of the head of the department of systems and computing.

- Super administrator module.

For the development of the solution, 4 iterations were considered:

Box 3

Table 2
Iterations of the model by prototypes

Iteration No.	Estimated time
Iteration 1- Prototyping students and administrators	9 weeks
Iteration 2.- Prototype adding teachers	3 weeks
Iteration 3.- Prototype-adding Artificial Intelligence model	8 weeks
Iteration 4.- Final product	1 week

Source: own elaboration

In each iteration, the 4 corresponding phases are carried out: Phase 1.- Communication, Phase 2.- Rapid Plan, Phase 3.- Modeling and Rapid Design and Phase 4.- Construction of the prototype.

For the iteration 1, the diagram of use case management of teachers is exclusive of the role of the head of the Office of Linking Projects, this module will have the functionalities of adding a new teacher, visualizing teachers, editing teachers and changing the status of a teacher Figure 3.

Box 4

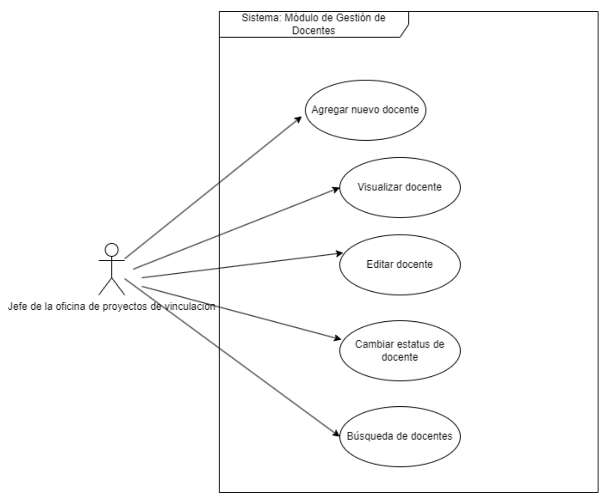

Figure 2
Teacher management module use case

Source: own elaboration

Iteration no. 3 Phase 1 Communication. Model of Artificial Intelligence, reflects the implementation of an Artificial Intelligence model based on machine learning with recommendation systems. These systems are capable of analyzing user behavior patterns and preferences to generate personalized recommendations.

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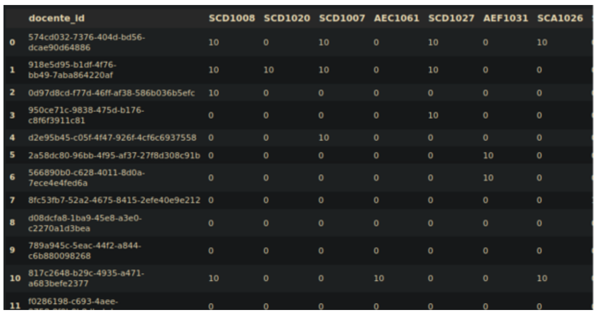
User profile. It refers to the set of subjects that each preliminary draft has. These subjects are chosen by the students at the time of registering their preliminary project. The total number of subjects is 32, so we work on a 32-dimensional plan.

Box 5



	docente_id	SCD1008	SCD1020	SCD1007	AEC1061	SCD1027	AEF1031	SCA1026
0	574cd032-7376-404d-bd56-dcae90d64886	10	0	10	0	10	0	10
1	918e5d95-b1df-4f76-bb49-7aba864220af	10	10	10	0	10	0	0
2	0d97d8cd-f77d-46ff-af38-586b036b5efc	10	0	0	0	0	0	0
3	950ce71c-9838-475d-b176-c8f6f3911c81	0	0	0	0	10	0	0
4	d2e95b45-c05f-4f47-926f-4cf6c6937558	0	0	10	0	0	0	0
5	2a58dc80-96bb-4f95-af37-27f8d308c91b	0	0	0	0	0	10	0
6	566890b0-c628-4011-8d0a-7ece4e4fed6a	0	0	0	0	0	10	0
7	8fc53fb7-52a2-4675-8415-2efe40e9e212	0	0	0	0	0	0	0
8	d08dcfa8-1ba9-45e8-a3e0-c2270a1d3bea	0	0	0	0	0	0	0
9	789a945c-5eac-44f2-a844-c6b880098268	0	0	0	0	0	0	0
10	817c2648-b29c-4935-a471-a683befe2377	10	0	0	10	0	0	10
11	f0286198-c693-4aee-	0	0	0	0	0	0	0

Figure 3
AI Teacher Utility Matrix

Source: own elaboration

On the other hand, in the construction of the prototype, the Login is shown, requesting the username, the password, the Create account option and Forgot your password? Figure 3.

Box 6

Figure 4
Prototype construction

Source: own elaboration

Results

Students must register the preliminary project, make corrections if required, register or join a dependency within the system.

It is important to identify the teacher's activity, to know the Preliminary Projects or Active Residencies, General Information and Academic Profile Figure 5

Box 7

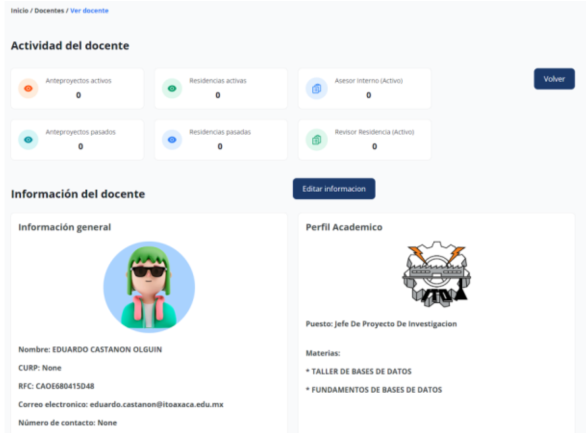


Figure 5
Teacher data

Source: own elaboration

You must also select the subjects related to your preliminary project. Figure 6. The system will make a recommendation from the Professional Residency Advisor.

Box 8

Figure 6
Subject Matter Compatibility

Source: own elaboration

Once the preliminary project has been reviewed and authorized, the data of the project of residence are registered, in them the name of the project, the type of project, the start date, date of completion, number of members are considered Figure 7.

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Box 9

Figure 7
Residency Project Data

Source: own elaboration

It is also a requirement to capture the Data of the Organization or Company: name, RFC, money order, cell phone number, email, mission, among others. Figure 8

Box 10

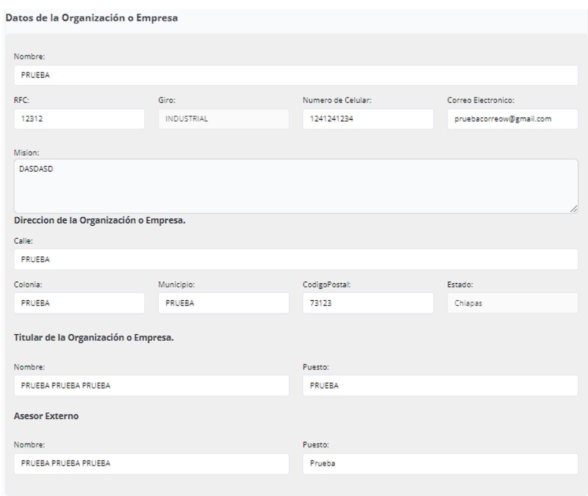

Figure 8
Organization or Company Data

Source: own elaboration

Conclusions

The development of the Web System of Professional Residence, through the implementation of an artificial intelligence model, has been an enriching experience in terms of knowledge, techniques and methodologies. This process has benefited the students involved, as well as the advisors and teachers who use the system.

The system created optimizes the Professional Residency procedure, allowing more efficient management.

Thanks to the integration of a recommendation model based on artificial intelligence, the time required for the selection of reviewers who analyze the preliminary projects has been significantly reduced, thus improving the efficiency of the process.

Throughout the different stages of the project, there were challenges and obstacles that had to be overcome, such as the definition of the requirements and functionalities of the system, the selection of the appropriate technology and the integration of various components.

However, as progress was made, it was possible to overcome these drawbacks and advance in the implementation of the system. In the third prototype, all the required functionalities were completed, resulting in a robust and efficient system, capable of managing large volumes of information and offering a personalized experience for each user.

In short, the implementation of this system has been a success, not only for the final result achieved, but also for the learning and growth that it has promoted in the team involved. This experience has strengthened the team's skills and laid the groundwork for future projects.

Declarations

Conflict of interest

The authors declare no interest conflict. They have no known competing financial interests or personal relationships that could have appeared to influence the article reported in this article.

Author contribution

Díaz-Sarmiento, Bibiana: Comprehensive support in the development of the project, evaluation and optimization of the development methodology used.

Román-Hernández, Esteban Daniel: Exhaustive analysis of the requirements to understand the processes of the Liaison Office of the Systems and Computer Department, those related to the Professional Residency.

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Morales-Hernández, Maricela: Comprehensive analysis of requirements to understand the needs in the Systems and Computing department – Linking Office, system development with a focus on quality and functionality, system implementation, ensuring a smooth transition, and detailed evaluation to measure its performance and effectiveness.

Salinas-Hernández, Fabiola: Initial and final evaluation of the project, methodology to be used; meetings with the team; Comparative analysis of methodologies, proposals for improvement and documentation of results.

Availability of data and materials

The data handled in the research of the Professional Residency Web System implementing an Artificial Intelligence model are available for consultation.

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To the teachers who spent time entering and testing the data. Evaluating the System and making the pertinent observations.

Abbreviations

MVC. Model View Controller.

RFC. Federal Taxpayer Registry

References

Antecedents

Maida, EG, Pacienzia, J. (2015). Metodologías de desarrollo de software [en línea]. Tesis de Licenciatura en Sistemas y Computación. Facultad de Química e Ingeniería “Fray Rogelio Bacon”. Universidad Católica Argentina

Basics

Bostrom, N. (2014). Superintelligence: Paths, Dangers, Strategies. Oxford University Press.

Brachman, R. J., & Levesque, H. J. (2004). *Knowledge Representation and Reasoning*. Morgan Kaufmann

Classifying Different Types of Recommender Systems. (2015, noviembre 14). BluePi. Retrieved from BluePi

Django. (n.d.). Django Project

Gerea, Carmen. Sánchez, Denisse (15 de marzo de 2021). Prototipo: qué es y para qué sirve.

Goodfellow, I., Bengio, Y., & Courville, A. (2016). Deep Learning. MIT Press.

Müller, V. C. (2020). AI Ethics. Cambridge University Press.

Pressman, R. S. (2002). Ingeniería del Software: Un enfoque práctico. McGraw-Hill Interamericana

Russell, S., & Norvig, P. (2016). Artificial Intelligence: A Modern Approach (3rd ed.). Pearson.

Rocca, B. (2021). Introduction to recommender systems - Towards Data Science. Medium. Towards Data Science.

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Article

Interactive business card prototype: promoting brands with augmented reality on social networks

Prototipo de tarjeta de presentación interactiva: impulsando marcas con realidad aumentada en redes sociales

Ortega-Gines, Héctor Bernardo*[a], Hernández-Guzmán, Julieta[b], Colmenares-Olivera, Esperanza[c] and Curioca-Varela, Yedid[d]

[a] Universidad Tecnológica de Tehuacán • X-8439-2018 • 0000-0003-0877-2227 • 687065
[b] Universidad Tecnológica de Tehuacán • ACR-3490-2022 • 0000-0002-3166-987X • 1014010
[c] Universidad Tecnológica de Tehuacán • LNQ-0286-2024 • 0000-0002-5804-5696 • 770219
[d] Universidad Tecnológica de Tehuacán • X-6919-2018 • 0000-0002-3060-4943 • 953765

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* [hector.ortega@uttehuacan.edu.mx]

Abstract

This project aims to develop prototypes of interactive cards using augmented reality (AR) to support SMEs and microenterprises in promoting and disseminating their products, goods, or services on social media. These interactive cards will offer an immersive and personalized experience, incorporating elements such as 2D and 3D objects, videos, images, sound, animations, and direct links to social media and websites, as well as other features like location and action buttons. With these capabilities, the project seeks to enhance brand visibility and reach in the digital environment, providing companies with an innovative and effective tool for their marketing strategy.

Goals	Methodology	Contribution
1.Develop a prototype of an interactive business card with augmented reality technology. 2.Evaluate the impact of augmented reality on brand promotion on social networks. 3.Improve the visibility and engagement of MSMEs through augmented reality.	Prototype development and implementation. 1. Development in Unity 2019.3.4f1 with Vuforia integration for image recognition. 2.Programming language: C# using MonoBehaviour in Visual Studio 2022. 3.Testing on Android devices starting with Lollipop version.	1.Innovation in business cards. Augmented reality allows for personalized interactive experiences. 2.Improvement of digital marketing. Increase visibility and engagement on social networks. 3.Technological accessibility. Works on Android devices from previous versions.

Prototypes, Interactive cards, Augmented reality

Resumen

Este proyecto tiene como objetivo desarrollar prototipos de tarjetas interactivas con realidad aumentada (RA) para apoyar a las MIPYMES y PyMEs en la promoción y difusión de sus productos, bienes o servicios en redes sociales. Estas tarjetas interactivas ofrecerán una experiencia envolvente y personalizada, incorporando elementos como objetos 2D y 3D, videos, imágenes, sonido, animaciones, y enlaces directos a redes sociales y páginas web, además de otras funcionalidades como ubicación y botones de acción. Con estas características, se busca potenciar la visibilidad y el alcance de las marcas en el entorno digital, proporcionando a las empresas una herramienta innovadora y eficaz para su estrategia de marketing.

Objetivos	Metodología	Contribución
1.Desarrollar un prototipo de tarjeta de presentación interactiva con tecnología de realidad aumentada. 2.Evaluar el impacto de la realidad aumentada en la promoción de marcas en redes sociales. 3.Mejorar la visibilidad y engagement de MIPYMES a través de la realidad aumentada.	Desarrollo del prototipo y su implementación. 1.Desarrollo en Unity 2019.3.4f1 con integración de Vuforia para el reconocimiento de imágenes. 2.Lenguaje de programación: C# utilizando MonoBehaviour en Visual Studio 2022. 3.Pruebas en dispositivos Android a partir de la versión Lollipop.	1.Innovación en tarjetas de presentación. La realidad aumentada permite experiencias interactivas personalizadas. 2.Mejora del marketing digital. Incrementa la visibilidad y engagement en redes sociales. 3.Accesibilidad tecnológica. Funciona en dispositivos Android desde versiones anteriores.

Prototipos, Tarjetas interactivas, Realidad aumentada

Citation: Ortega-Gines, Héctor Bernardo, Hernández-Guzmán, Julieta, Colmenares-Olivera, Esperanza and Curioca-Varela, Yedid. [2024]. Interactive business card prototype: promoting brands with augmented reality on social networks. Journal Computational Simulation. 8[19]-1-9: e40819109.

Introduction

In an increasingly digital and competitive world, businesses face the constant challenge of capturing the attention of consumers and differentiating themselves in the marketplace. This challenge is particularly relevant in the context of micro, small and medium-sized enterprises (MSMEs and SMEs), which often have limited resources but a strong need for visibility. In this context, innovation in promotion and dissemination strategies becomes a key factor in achieving business success, and this is where interactive business cards, powered by augmented reality (AR) technology, come into play.

The importance of this topic lies in AR's ability to transform traditional business cards into interactive digital tools that not only capture the user's attention (Azuma, 1997), but also strengthen the connection between brands and their audiences. In a market where digital interactions dominate, traditional business cards (Wiederhold & Riva, 2019) have begun to lose relevance. However, by integrating AR technology, it is possible to revitalise this medium, offering an immersive and personalised user experience that can distinguish a brand in an information-saturated environment.

The added value of interactive AR business cards over other techniques lies in their ability to combine the tangibility of a physical card with the interactivity of digital media. Unlike other digital marketing strategies, which can be impersonal or easily forgotten, these cards allow for direct and memorable interaction, facilitating a deeper and more lasting connection with the consumer. In addition, they offer synergistic integration with social media and other digital platforms, amplifying their reach and effectiveness in brand promotion

Each of the features of these interactive cards brings specific value to the user experience. The inclusion of 2D and 3D objects, videos, images, sound, animations and direct links to digital platforms not only enriches the content presented, but also allows for customisation that can be tailored to the specific needs of each brand. These cards not only attract attention, but also facilitate an emotional bond with the user, which can translate into greater customer loyalty and conversion.

The problem to be solved with this study focuses on the need for MSMEs and SMEs to improve their visibility and promotion in an increasingly digital and competitive market. The central hypothesis of this research is that the implementation of interactive AR business cards will allow these companies to significantly improve their visibility and promotion on social networks, providing a more engaging and memorable user experience. The article is structured in several sections to comprehensively address the development of this innovative prototype. First, a theoretical framework is presented that contextualises the evolution of business cards and AR in the field of digital marketing. Next, the methodology used to design and test the prototype is detailed, followed by an analysis of the results obtained and their potential impact on brand promotion. Finally, conclusions and recommendations for future research and practical applications of this technology in digital marketing are offered.

Methodology

Preliminary considerations

Assessment of the State of the Art

Before starting with the design and development of the AR interactive business card prototype, a thorough assessment of the state of the art in terms of available technologies and tools for integrating AR into mobile devices was carried out, specifically with the aim of improving the connection with social networks and facilitating access to the companies' website. The analysis included the study of existing platforms and solutions that use AR for brand promotion, as well as integration with social networks through mobile devices. In this regard, the research revealed that while there are several AR solutions on the market, few are optimised for business cards with direct access to social media. This gap in the market reinforces the need and feasibility of a prototype that offers an effective solution for MSMEs and SMEs looking to improve their digital visibility.

Compatibility with Mobile Devices

To ensure accessibility and wide use of the prototype, it was decided to focus the development on mobile devices with Android operating system, starting from version Lollipop (5.0 - 5.1.1), released on 12 November 2014.

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This version was chosen because it is still used on a wide variety of mobile devices, both mid-range and low-end, ensuring that the prototype can reach a wider audience without being limited by the technical capabilities of newer devices.

The selection of Android also responds to its high global market share, especially in regions where small and medium-sized businesses operate most frequently.

Using Vuforia for Image Scanning

The choice of Vuforia as the SDK for image recognition and AR implementation was key in the development of the prototype. Vuforia was selected due to:

- Previous experience: The development team had already worked with Vuforia in other AR prototypes, which guarantees a deep knowledge of its capabilities and its integration with Unity.

- Free version: The free version of Vuforia is a stable and reliable solution for projects of this type, especially for small companies looking to minimise costs without compromising quality.

- Stability and accuracy: Vuforia offers 98% accuracy in scanning images and objects, ensuring a smooth and uninterrupted user experience. This is essential to ensure that the interactive business card works quickly and efficiently when users scan the physical card image with their mobile devices.

Technical Considerations

Vuforia was chosen not only for its image recognition accuracy, but also for its ability to adapt to a wide range of mobile devices, ensuring that the scanning and activation of the AR experience is efficient on low to mid-range devices, which represent a significant part of the target market.

Prototype Design

The design of the interactive business card prototype starts with the conceptualisation of the desired functionalities and user experience.

The objective is to create a card that, when scanned with a mobile device, displays interactive content such as 2D models, videos, animations, and direct links to digital platforms.

Box 1

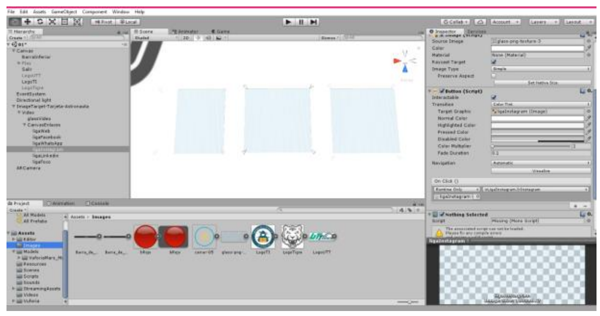

Figure 1
Interactive model content
Source: Own elaboration

Tools and Software Used

- Unity Game Engine 2019.3.4f1: This version of Unity was selected for its compatibility with the AR Foundation, a framework that facilitates the development of augmented reality applications for iOS and Android. Unity allows the creation, management and visualisation of 3D and 2D elements to be integrated into the business card.

- Vuforia SDK: This development kit is used for image detection and tracking, which is essential for the physical card to be recognised and ‘augmented’ by the mobile device. Vuforia integrates with Unity, allowing AR elements to be precisely fitted onto the scanned card.

- Blender/3ds Max: 3D modelling tools like Blender or 3ds Max are used to create the objects and animations that will be displayed in the AR experience. These models are imported into Unity to be integrated into the augmented reality scene.

- Adobe Photoshop/Illustrator: these are used to design the physical business card, ensuring that the design is not only attractive, but also compatible with Vuforia's requirements for image tracking.

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Prototype Development:

1. Components: Interactive elements that would compose the business card were defined, such as 2D models, animations, images, videos and interactive links. These components were chosen with the aim of creating an immersive and engaging experience.

Box 2

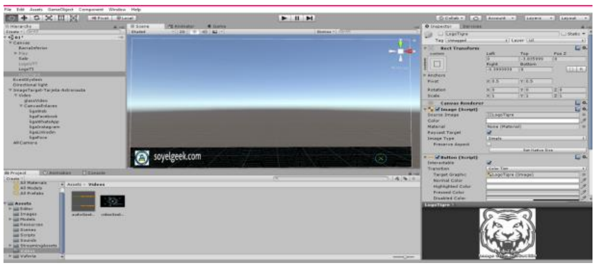

Figure 2
Embedded video and audio
Source: [Own elaboration]

Box 3

Figure 3
Integrated business card
Source: [Own elaboration]

2. Creation of the Physical Card: The business card is designed in Adobe Photoshop or Illustrator, incorporating graphic elements that will facilitate the recognition of the image by Vuforia (Vuforia, 2022).

Box 4

Figure 4
Final card design
Source: [Own elaboration]

Box 5

Figure 5
Card presentation with embedded social media images
Source: [Own elaboration]

Box 6

Figure 6
Card animation test
Source: [Own elaboration]

1. Setup in Unity: A new project is created in Unity 2019.3.4f1, Vuforia is integrated and a 2D scene is set up. 2D models and other previously created multimedia elements are imported.

Box 7

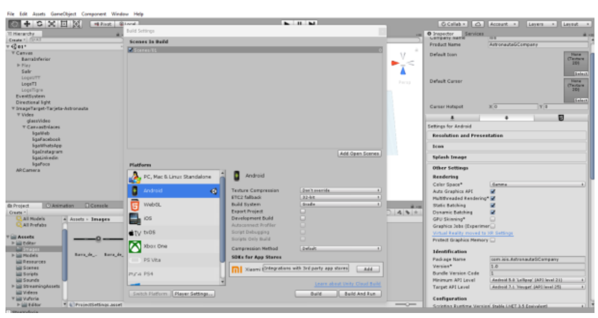

Figura 7
General configuration of Unity
Source: [Own elaboration]

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Box 8

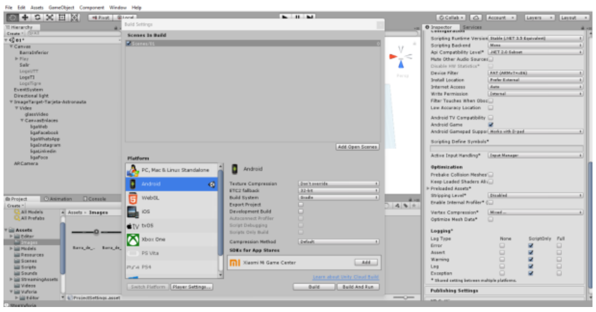

Figure 8

Configuring Unity for Android

Source: [Own elaboration]

1. Vuforia configuration: In Unity, the card image is added as an "Image Target" in Vuforia. 3D models and other interactive elements are positioned relative to this image target, ensuring that they display correctly when the card is scanned.

Box 9

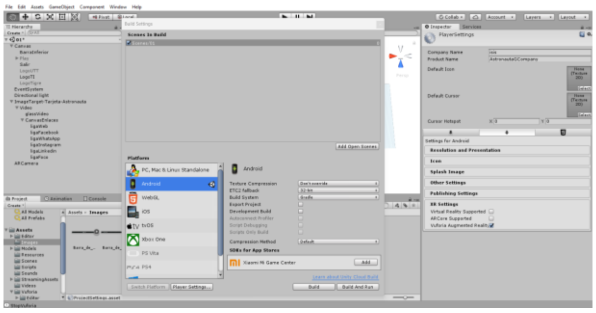

Figura 9

Configuring Unity to use Vuforia for Augmented

Source: [Own elaboration]

Box 10

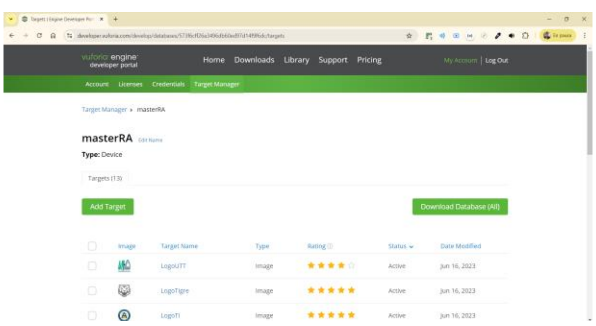

Figure 10

Downloading the scoreboards from Vuforia

Source: [Own elaboration]

1. Interactivity programming: Using C# in the Unity IDE (Unity Technologies, 2022), user interactions with AR elements are programmed, such as touching an object to play a video or animation, or clicking a button to open a direct link to a social network.

Box 11

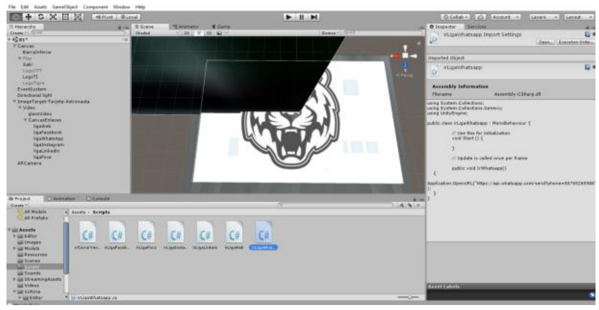

Figura 11

Incorporation of the marker

Source: [Own elaboration]

Box 12

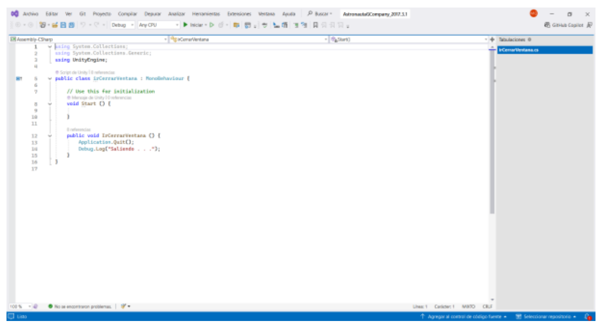

Figure 12

C# Scripts

Source: [Own elaboration]

2. Links and Calls to Action (CTAs): Interactive CTAs are incorporated into the AR experience, allowing users to share their experience on their own social networks with a single click, or to visit the company's page on specific platforms. These links are designed to be accessible directly from the AR experience, enhancing integration with social networks. Links to platforms such as Instagram, Facebook, LinkedIn, Whatsapp, company website, etc. are created.

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Box 13

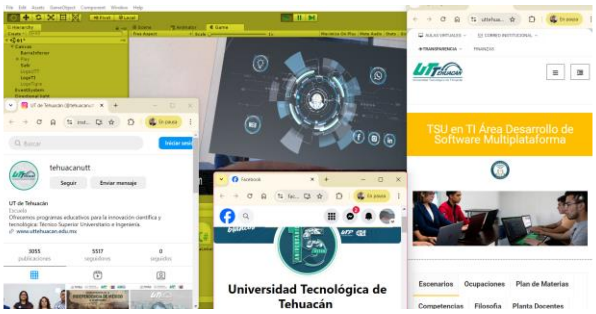

Figure 13 Visualisation of social media

Source: [Own elaboration]

3. Initial Testing and Adjustments: Preliminary tests are performed on mobile devices to adjust the position, scale and behaviour of interactive elements, ensuring a smooth and accurate user experience.

Box 14

Figure 14 Tests on a PC

Source: [Own elaboration]

Box 15

Figure 15 Testing on mobile devices

Source: [Own elaboration]

Social Media Implementation

One of the main features of the prototype is its ability to seamlessly integrate with social media platforms. Two methods of interaction were designed for this purpose:

1. Direct Links. Buttons are included which, when tapped, redirect users to the brand's social media profiles (Facebook, Instagram, Twitter). These links were created through embedded external URLs.

Box 16

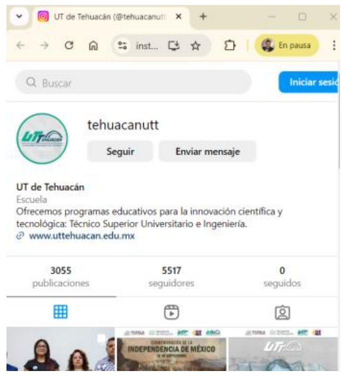

Figure 16 Instagram league

Source: [Own elaboration]

Box 17

Figure 17 Facebook league

Source: [Own elaboration]

2. Multimedia content. Promotional videos are loaded directly from the business card, allowing users to view content without leaving the AR experience.

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Box 18

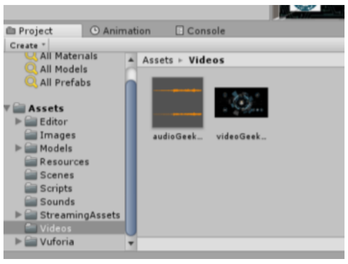

Figura 18
Project-integrated multimedia
Source: [Own elaboration]

Interactive Features

- Promotional videos: Videos integrated into the experience allow brands to tell stories or promote products.

- 2D Animations: Custom animations reinforce the brand's visual identity, providing a dynamic and engaging experience.

- Social Media Buttons: These buttons redirect to official profiles, facilitating the connection between the user and the brand.

Testing and Validation

Testing Phase

To evaluate the effectiveness of the prototype, tests were carried out with a group of users divided into two categories:

1. Experimental group: Users who interacted with the interactive AR business card.
2. Control group: Users who received a traditional business card.

The profile of the test subjects included small entrepreneurs, freelancers and designers, who are potential users of these cards in business environments.

The results will be presented in a separate research focused on data analysis. The effectiveness of the interactive business card will be evaluated. By carrying out a series of tests with the two groups mentioned above, which are part of the brand's target audience. These tests will focus on two main aspects: the user experience and the impact on brand promotion.

Technical validation

The card was tested on several mobile devices of different ranges (high, medium, low) to ensure its performance and functionality. Testing included:

- Experience Load Time: The time from when the user scans the marker until the AR experience is deployed on their device was measured.

- Battery Consumption and Performance: Tests were conducted to verify that prolonged use of AR does not significantly affect device performance.

Results

The development of the interactive business card prototype with augmented reality has enabled the implementation of an innovative tool for the promotion and dissemination of products, goods or services of a company, contributing to brand positioning in a highly competitive environment. The results of this research and development can be divided into several key areas, covering both the design of the software and the necessary tools and technical skills. User Experience (UX). The prototype has been designed with a focus on user experience, aiming to offer an attractive, intuitive and fluid interaction. The main objective is to ensure that the digital business card, when scanned with a mobile device, displays interactive elements that strengthen the connection between the brand and the end user.

The choice of the C# programming language was fundamental, as it is the main language used in the Unity development environment. Its ability to handle events, object-oriented programming logic and flow control allowed for a solid construction of the interactive behaviour of the prototype.

C# scripts were used to manage the interaction between AR elements and user actions, such as tapping to display animations or opening links to the company's social networks.

One of the most important elements of the Unity development was the use of the MonoBehaviour class, which provides access to methods that handle events within the Unity engine.

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Microsoft Visual Studio 2022 was the tool of choice for writing and debugging Unity code. Visual Studio provides a robust and efficient environment for development, with advanced debugging and project management features, which made it easy to identify bugs and optimise code.

Vuforia Engine was used to implement the physical card scanning capability and display AR elements. Image recognition through Vuforia proved to be highly effective and accurate, with stable performance even on low-end and mid-range mobile devices.

Conclusions

The prototype proved to be a viable technical solution, offering an interactive experience that combines multimedia elements, such as animations, videos and 2D objects, with direct links to social networks and company websites. The efficiency of the prototype in terms of image recognition and interactive content display was high, using tools such as Vuforia and the Unity development engine. This ensures a stable and functional experience for users, contributing to improved engagement and brand promotion.

The interactive AR business card significantly expands the possibilities for promotion and dissemination in the digital environment. By providing a personalised and immersive experience, companies can improve brand awareness and increase interaction with their target audience. The prototype not only facilitates access to relevant digital content, but also generates higher user attention retention compared to traditional business cards.

The prototype has proven to be adaptable to a wide range of Android OS mobile devices from version Lollipop (5.0 - 5.1.1), ensuring a wider reach for companies wishing to use this technology. The choice of tools such as Vuforia for image recognition ensures broad compatibility, while the use of C# and MonoBehaviour in Unity provides flexibility in the design and implementation of interactive functionalities. In addition, the customer has to install the application on his mobile phone in case he wants to take the application with him on his mobile phone. Therefore, it is recommended for use in promotional campaigns and dissemination of the product, good or service.

Declarations

Conflict of interest

The authors declare that they have no conflict of interest in relation to the development of the interactive business card prototype with augmented reality.

They have no competing financial interests or personal relationships that could have influenced the results, analysis or conclusions presented in this article.

Authors' contribution

Ortega Gines, Héctor Bernardo: Contributed to the project idea and development of the prototype.

*Hernández Guzmán, Juliet*a: Contributed to the research method and technique.

Esperanza Colmenares, Esperanza: Contributed to the tests with an experimental group and a control group.

Curioca Varela, Yedid: Contributing to the testing and validation of the prototype.

Availability of data and materials

The data and materials used during the development of this research are available upon written request to the corresponding author. This includes the source code of the prototype developed in Unity, the multimedia resources integrated in the interactive presentation card, as well as the data obtained during the validation tests carried out.

Funding

The present research did not receive any funding for the prototype and research.

Abbreviations

AR	Augmented Reality
RA	Augmented Reality
UX	User Experience
CTAs	Links and Calls to Action
SDK	Software Development Kit
MIPYMES	Micro, Small and Medium Enterprises
PyMEs	Small and medium-sized enterprises
2D	Two Dimensions

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References

Basic

Azuma, R. T. (1997). A survey of augmented reality. *Presence: Teleoperators & Virtual Environments*, 6(4), 355-385.

Unity Technologies. (2022). *Unity Manual: Introduction to scripting in C#.* Unity Technologies.

Vuforia. (2022). *Vuforia Developer Library: Image recognition and tracking in augmented reality*. PTC Inc.

Wiederhold, B. K., & Riva, G. (2019). Augmented reality in marketing: Bridging the digital and physical worlds. *Cyberpsychology, Behavior, and Social Networking*, 22(1), 57-61.

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Article

Advances in CPR: Design and Validation of the *RescueBeat* System for Compression and Ventilation

Avances en RCP: Diseño y validación del sistema *RescueBeat* para compresión y ventilación

Martínez-Torres, Rosa Elia[a], Mendoza-Razo, Juan Arturo*[b], Padrón-Vázquez, Alejandro[c] and Espinosa Juárez, Cid Tonatiuh[d]

[a] Instituto Tecnológico de San Luis Potosí, TecNM • X-3124-2018 • 0000-0001-8936-9207 • 953355
[b] Instituto Tecnológico de San Luis Potosí, TecNM • LWK-3088-2024 • 0000-0002-, 9289-8908 • 82304
[c] Instituto Tecnológico de San Luis Potosí, TecNM • 0009-0009-7509-5802
[d] Instituto Tecnológico de San Luis Potosí, TecNM • 0009-0001-7192-4265

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* ✉ [juan.mr@slp.tecnm.mx]

Abstract

Advances in CPR: design and validation of the *rescuebeat* System for compression and ventilation

Objectives	Methodology	Contribution
Create an intuitive and accessible device for people with no prior knowledge of first aid, to provide effective CPR by minimizing the response time between compression and ventilation.	Applied research, with a mixed approach and explanatory management. The design of the RescueBeat system is developed with the methodology of Pahl and Beitz (2007), programming and calculations based on vital body operations.	It considers a technological contribution in the area of mechatronics; It has a direct impact on the emergency area of the health area.

Cardiopulmonary Reanimation CPR, corporeal compression and ventilation, Emergency

Resumen

Avances en RCP: diseño y validación del sistema Rescuebeat para compresión y ventilación

Objectives	Methodology	Contribution
Crear un dispositivo intuitivo y accesible para personas sin conocimientos previos de primeros auxilios, con la finalidad de brindar RCP efectiva al minimizar el tiempo de respuesta entre compresión y ventilación.	Investigación aplicada, con enfoque mixto y manejo explicativo. El diseño del sistema RescueBeat, es gestado con la metodología Pahl y Beitz (2007), programación y cálculos en función de operaciones vitales corpóreas.	Considera una aportación tecnológica en el área de la mecatrónica; tiene un impacto directo en el área de las emergencias del área de la salud.

Reanimación cardiopulmorar RCP, compresiones y ventilación corpóreas, emergencias

Citation: Martínez-Torres, Rosa Elia, Mendoza-Razo, Juan Arturo, Padrón-Vázquez, Alejandro and Espinosa Juárez, Cid Tonatiuh. Advances in CPR: Design and Validation of the *RescueBeat* System for Compression and Ventilation. Journal Computational Simulation. 8[19]-1-7: e60819107.

Introduction

Cardiovascular diseases are one of the main threats to health, being the number one cause of death worldwide, and it is estimated that this event will continue to increase in the coming decades. The prevention and treatment of this type of diseases is based on the progress and technological advance of science and also on the prompt response of the emergency in the area of health. The aim of this article is to prioritise the study of cardiorespiratory arrests by presenting a technological development that provides cardiopulmonary resuscitation (CPR) (Dávila, 2019).

The practice of CPR involves procedures that aim to perform the work of the heart when it stops working, in addition to bringing blood to the body, which can reduce the mortality rate. For correct resuscitation, factors such as the amount and frequency of compressions and the necessary ventilations are considered (Zuluaga and Agudelo, 2020).

A paradigm in the implementation of these techniques holds that the success rate is low or null, however, recent studies and techniques, allow to know and study the functions of the body and the conditions that can be presented, allowing to integrate areas of science to propose solutions (Zuluaga and Agudelo, 2020).

Engineering has had a beneficial impact on the area of medicine, creating devices with countless applications for the care of diseases. The design and development of technological tools focuses theory towards experimentation with disruptive technologies (Serna, 2022).

This paper presents the methodological stage of a research, which concludes with a technological development in prototype format using the principles of CPR; called RescueBeat, this development promotes the prevention of human errors that commonly occur in stressful situations, as well as the decrease in effectiveness that can be caused by fatigue during compressions (Serna, 2022).

The aim of RescueBeat is therefore to reduce mortality caused by the simultaneous arrest of cardiac and respiratory function.

The methodology used in this research combines the design approach of Pahl and Beitz (2007), with the expertise of healthcare professionals, and utilised tools such as a programming development platform, electrical design simulation software and computer-aided design.

Creating a device that is easy to use, intuitive and accessible to people without prior knowledge of first aid, leads to a particular design that meets the operations sought: compressions and ventilation; the development presented achieves the objective of being able to be manipulated easily by anyone, and opens lines of research and development to continue contributing to this project for the benefit of health in emergency situations.

Literary bases

Performing correct CPR involves knowing the corresponding procedures and techniques, which is why the American Heart Association (AHA) mentions the characteristics that should exist when providing this assistance, seeking to increase the victim's chances of survival (AHA, 2021).

The CPR procedure in adults consists of placing the base of the hand on the centre of the chest, specifically on the sternum, supported by the other hand. Compressions should be performed with the aim of sinking the area by 4 to 5 centimetres and at a rate of 100-120 compressions per minute. Ventilations are recommended for a high chance of success (AHA, 2021).

Standard compressions can be performed where the minimum or maximum rate mentioned above is met, while respecting the chest to return to its initial position. Due to the effort required to meet this condition, the so-called 30:2 method was established, where 30 compressions and 2 ventilations are performed with each ventilation lasting approximately 1 second each. As a priority, compressions should not be interrupted for more than 10 seconds (Pansky and Gest, 2015).

Knowledge of human anatomy is the basis for applying chest compressions to the thorax, as it acts as a mechanical pumping mechanism and is essential for lung ventilation.

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Composed of the thoracic vertebrae, 12 pairs of ribs and the sternum, it forms a cavity that expands and contracts with a determined rhythm, which causes the muscular action that allows the flow of air into the lungs - respiratory function - and also has a protective role for vital organs: heart and large blood vessels (Pansky and Gest, 2015).

Methodology and development

A design methodology based on the principles of Pahl and Beitz (2007) is implemented. It starts with a thorough clarification of the task, identifying key product needs and functions. Various materials are explored, assessing technical and economic feasibility. Computer-aided design (CAD) tools, rapid prototyping and programming development software were used to realise the design. Each stage of the process included a trial and error system, aiming for the final prototype to meet the established requirements.

Starting from the identification of the problem to be solved, and the information related to the required anatomical operations, an analysis of the actions to be performed by RescueBeat was carried out, which was translated into a function diagram that clearly organises the priority of each task as well as visualising a basic alternative solution for each one of them, where the operational needs of the person who will manipulate it, as well as those who will be assisted, can be satisfied (Figure 1).

Box 1

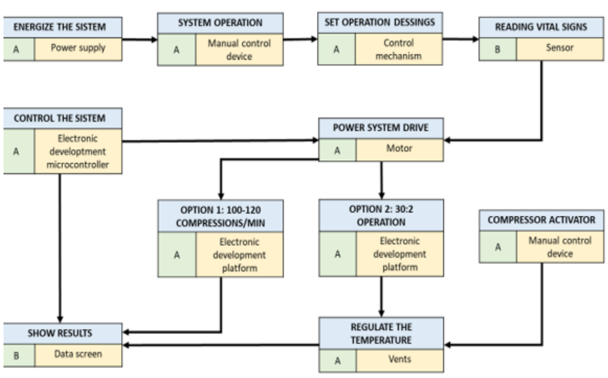

Figure 1
Functional Diagram

Own Elaboration

Based on this activity, an analysis was carried out to identify parameters that represent advantages and disadvantages, and the different materials and tools explored to meet the basic operational needs are presented in table 1, which shows two of the total elements evaluated as examples

Box 2

Table 1
Identification and ranking table of selection criteria

Energising the system		
Option	**Advantages.**	**Disadvantages**
Battery bank CD	Portable	Duration Accessible Cost Efficiency
Source CA	Efficiency Cost Duration	Laptop Accessible
Operate the system		
Option	**Advantages**	**Disadvantages**
Switch	Simplicity Space Maintenance	Duration Cost
Button	Simplicity Cost Space Maintenance	Duration
Sensor	Maintenance Simplicity	Duration Cost Space

Own elaboration

With the information obtained, the activity of evaluating the options explored is considered, where a value is assigned on a Likert-type scale with levels from 1 to 3, where 1: not useful, 2: may become useful with some adjustments, 3: useful. Based on the comparison criteria for each of the systems, table 2 is created, which for the purposes of this article, is subject to the first two elements analysed.

Box 3

Table 2
Proposed options appraisal table

Energising the system						
Material	Portable	Acces	Efic	Durac	Cost	Total
Battery CD	3	1	2	2	2	10
AC source	1	2	3	2	3	11
Operate the system						
Material	Simp	Manten	Esp	Durac	Costo	Total
Switch	3	3	3	1	1	11
Button	3	3	3	2	3	14
Sensor	3	3	2	2	2	12

Own Elaboration

Martínez-Torres, Rosa Elia, Mendoza-Razo, Juan Arturo, Padrón-Vázquez, Alejandro and Espinosa Juárez, Cid Tonatiuh. Advances in CPR: Design and Validation of the *RescueBeat* System for Compression and Ventilation. Journal Computational Simulation. 8[19]-1-7: e50819107.
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Finally, the highest totals were extracted and a list is created and recorded in table 3:

Box 4

Table 3
Selection of elements

Function to be fulfilled	Option chosen:	Score:
Energise the system	AC source	11
Powering the system	Button	14
Set system configuration	Button	14
Read vital signs	Pulse sensor	13
Actuating the power system	Stepper motor	13
Controlling the system	Arduino	14
Operation option 1 and option 2	Arduino	13
Operate compressor	Solenoid valve	12
Regulating the temperature	35 litre compressor	14
Display data	Display 16x2 with Ic2 module	12
Extra: Prototype housing	Wood	13

Own Elaboration

Once the optimal elements were selected, the development of the device was started by making computer aided drawings (CAD) using SolidWorks software as a useful resource. In order to have a clearer idea of the approximate dimensions of the system.

Figure 2 shows the model of the housing made in SolidWorks, in which the approximate size and the spaces designated for each of the elements can be appreciated.

Box 5

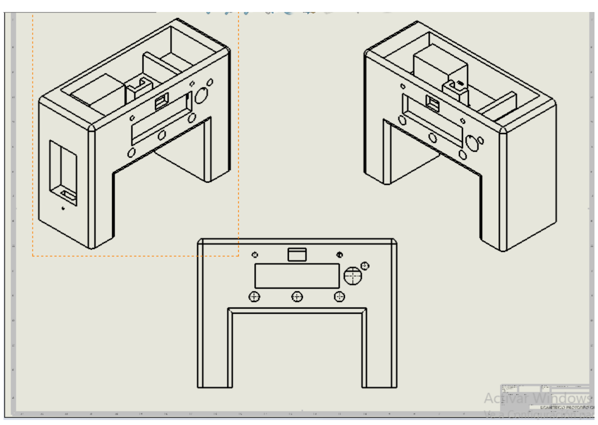

Figure 2
Base design of the RescueBeat
Own Elaboration

Simultaneously, programming was carried out to automate the desired functions, using software with a development board - microcontroller - which allows the entire system to be governed: basic aspects of information input and output, optimal development of functions. This programming design uses a basic C++ language, allowing a clear understanding of its operation and ease of manipulation in reference to the 30:2 compression-ventilation (figure 3).

Box 6

```
#include <Stepper.h>
#include <LiquidCrystal_I2C.h>
#include <Wire.h>
#include <Adafruit_GFX.h>
#include <Adafruit_SSD1306.h>
#include <SPI.h>

// Definición de constantes
int CICLOSDECOMPRESION=3;
const int boton1 = 2;
const int boton2 = 4;
const int boton3 = 13;
int red = 3;
int blue = 5;
int buffer = 6;
                              /*const int stepsPerRevolution = 300;
                              const int pin1 = 8;
                              const int pin2 = 9;
                              const int pin3 = 10;
                              const int pin4 = 11;*/
const int PUL = 8;  // Pin para la señal de pulso
const int DIR = 9;  // Pin de dirección del motor
const int EN = 10;   // Pin Enable
int i=0;
int j=0;
const int PASOSPORREVOLUCION = 4000;
const int VELOCIDAD = 1200;  // Tiempo de espera entre pasos (micro
int rele = 12;
```

Figure 3
RescueBeat programming code
Own Development

The electrical connection diagram (Figure 4) shows the microcontroller board at the centre of the circuit, including the pulse sensors, the operating buttons, the motor controller, the 16x12 i2c lcd display, and the relay responsible for opening and closing the compressor opening and closing valve.

Box 7

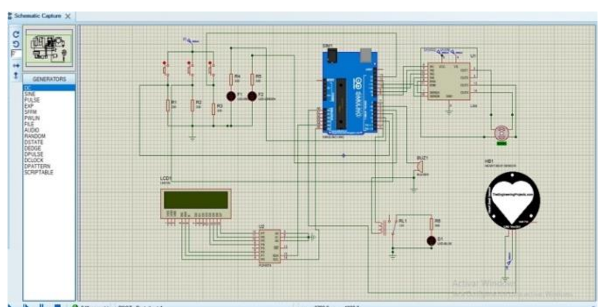

Figure 4
Electrical diagram simulated in Proteus
Own Elaboration

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Some of the calculations based on literature that are indispensable in relation to compressions and ventilation are shown:

Equation for pressure calculation

Referred to as Pascal's principle, it establishes that any change in pressure at one point of an enclosed fluid is transmitted in its entirety and without decrease to all points of the fluid. In the mechanics of materials it is used when a material is subjected to loads and is expressed by the following formula, where P is pressure and A is area.

$$P = \frac{F}{A} \quad (1)$$

Equation for area calculation

Allows to calculate the surface of different plane figures with applications in different areas.

$$A = B * h \quad (2)$$

Development of force calculation

Considering for simplicity the sternum as a rectangle with the following dimensions:

$L = (10 + 5 + 3)cm = $ 18cm

$B = 6cm$

Where:
L= Length in metres (m)
B= Base in metres (m)
Calculating the area of the rectangle where:

$$A = \frac{18cm * 6cm}{10000}$$

We obtain from Equation 2 that the area of the sternum is:

$$A = 10.8x10^{-3}\ m^2$$

With the data obtained from the previous study on the average thrust force, we take the highest impact force of 227N and substitute it into equation 1.

Where:
P: Pressure measured in Pascals (Pa).
F: Force in units of Newtons (N)
A: Area measured in square metres (m^2)

With the data obtained and applying the formula we obtain that:

$$A = 10.8x10^{-3}m^2$$

$$F\_aproximada = 227N$$

$$P = \frac{227N}{10.8x10^{-3}\ m^2} = 21.01\ KPa$$

L he ideal pressure for resuscitation is not fixed, but depends on the person applying it, as these characteristics vary according to each individual. Factors such as age, physical training and lifestyle directly influence the amount of force that can be safely and effectively applied, therefore, the value mentioned is only a starting point for calculation (Caeiro, González and Guede, 2013).

Considering that the maximum pressure applied to the cortical bone is 215 MPa, and the approximate pressure that can be applied when performing chest compressions is 21.01 KPa, it is evident that a stress that exceeds the capabilities of the cortical bone is not performed, thus avoiding a fracture.

Results

From the construction and testing of the developed CPR mechanism device, it was demonstrated that it is possible to implement a compression and ventilation system that provides effectiveness and safety. The prototype achieved a compression rate of 100 compressions per minute and a ventilation rate of 12 breaths per minute, which is within the parameters recommended by the American Heart Association for CPR.

In addition, the ventilation system was verified to be capable of providing an adequate volume of air for artificial respiration, suggesting that the prototype is effective in providing respiratory support in emergency situations.

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Box 8

Figure 5a, b

RescueBeat, technological development

Own Elaboration

Conclusions

This technological development has demonstrated the feasibility of an innovative CPR mechanism that combines compression and ventilation. The results suggest that this system can be a valuable tool in emergency medical care, especially in situations where fast and effective response is crucial.

The research also highlights the importance of innovation and the development of technologies that improve emergency medical care. In the future, it is possible that technological systems may become a standard tool in medical care, which could significantly improve outcomes for patients suffering cardiac arrest.

Ultimately, it demonstrates the importance of research and development in improving emergency medical care, and highlights the need to continue to innovate and develop life-saving technological devices to achieve a better quality of life as a society, also highlighting the right to health.

Declaration

Conflict of interest

The authors declare no interest conflict. They have no known competing financial interests or personal relationships that could have appeared to influence the article reported in this article.

Author contribution

The specific contribution of authors a and b focuses on the scientific and technical direction of the research project, assignment of methodologies and tools, as well as inter-institutional management for dissemination and publication; On the other hand, authors c and d, build the prototype presented based on proposed elements.

Availability of data and materials

The data obtained from this research are accessible through the technical report that belongs to the Technological Institute of San Luis Potosí, in the persons of the authors who intervene in it.

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There is no funding for the manufacture of the prototype or its dissemination. The authors assume this responsibility.

Abbreviations

CPR – Cardiopulmonary resuscitation.

References

AHA (2021). Heartsaver student Book. American Heart Association.

Davila, C. (2019). Trend and impact of cardiovascular disease mortality in Mexico, 1990-2015. Cuban Journal of Public Health. 2019;45(4)

Caeiro, J., González, P., Guede, D. (2013). Biomechanics and bone (and II): testing at different hierarchical levels of bone and alternative techniques for the determination of bone strength. Journal of Osteoporosis and Mineral Metabolism, 5(2).

Pahl, G., & Beitz, W., (2007). Engineering Design, a systematic approach. England: Springer.

Pansky, B., Gest, T. (2015). Lippincott's concise illustrated anatomy: Thorax, abdomen, and pelvis (2nd ed.). Amolca.

Serna, E., Serna, A. (2022). Engineering and life science: Symbiotic relationship for human survival. *Entramado*, vol. 18, no. 2.

Zuluaga. M., Agudelo. C., Posada, S. (2020). Traumatic cardiac arrest: how can we intervene in the emergency department. Medicina U.P.B., vol. 40, no. 1.

[[Title in TNRoman and Bold No. 14 in English and Spanish]

Surname, Name 1st Author*[a], Surname, Name 1st Co-author[b], Surname, Name 2nd Co-author[c] and Surname, Name 3rd Co-author[d] [No.12 TNRoman]

[a] Affiliation institution, Researcher ID, ORC ID, SNI-CONAHCYT ID or CVU PNPC [No.10 TNRoman]
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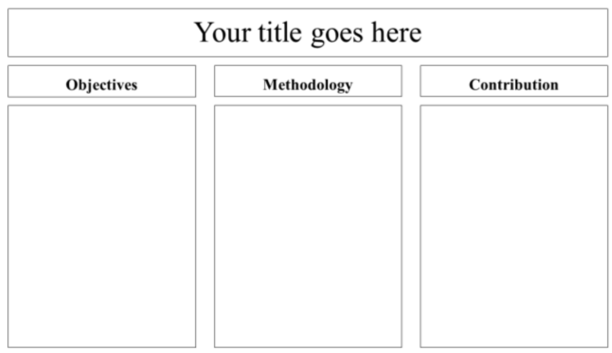

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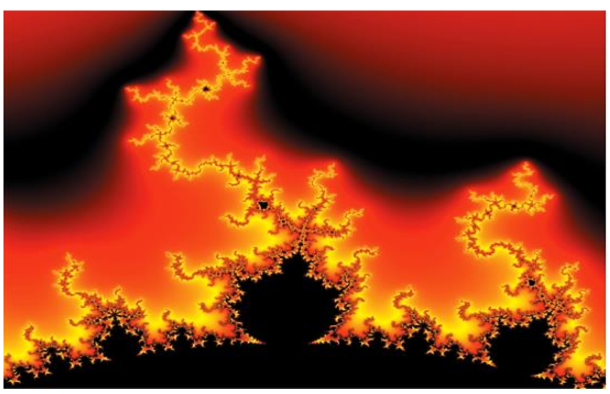

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$$Y_{ij} = \alpha + \sum_{h=1}^{r} \beta_h X_{hij} + u_j + e_{ij} \qquad [1]$$

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The results shall be by section of the article.

Conclusions

Clearly explain the results and possibilities of improvement.

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Tables and adequate sources.

<u>The international standard is 7 pages minimum and 14 pages maximum.</u>

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The authors declare no interest conflict. They have no known competing financial interests or personal relationships that could have appeared to influence the article reported in this article.

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Specify the contribution of each researcher in each of the points developed in this research.

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Indicate the availability of the data obtained in this research.

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Indicate if the research received some financing.

Acknowledgements

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List abbreviations in alphabetical order.

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ANN	Artificial Neural Network

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