Designing a Fuzzy Smart System for Energy Conservation for Common Sustainable Smart Home

Seyed Omid Fatemi[1], Vahid Ghobadian[2]*, Behrouz Mansouri[2]

Architectural Engineering Department, UAE Branch, Islamic Azad University, Dubai, UAE
Architectural Engineering Department, Central Tehran Branch, Islamic Azad University, Tehran, Iran. vah.qobadiyan@iauctb.ac.ir

Abstract

Iran is a vast country rich with energy resources. Perhaps, such unlimited energy resources were the reason to keep us in a dream of abundance, and as a result, neglecting justifiable energy conservation. Buildings are one of the main energy consumption and waste sources, and regretfully, still many of them are constructed violating modern engineering rules and solely through experimental and traditional methods. Air conditioning systems are still calculated and designed using estimation. However, we have to know such methods are obsolete in developed countries since ages ago, and we shall commence with a new determination and effort right away if we would like to reach the Global trend. Fortunately, many of the ways have been taken before us, and have certain instructions. In late 20th century and upon development of smart technologies, development of communication and internet networks, sensor networks and sensors, extensive efforts and studies started to use such group of technologies to present solutions to improve humans' lives. Using IOT to control the house smartly has been one of the study fields during recent years. The suggested method tries to improve the house smart control for energy conservation. The used sensors are heat and humidity sensors with the duty of monitoring smart home. In this article we plan to suggest optimized smart method to control smart sustainable common home relays smartly. The sensors data is entered into the sustainable common home smart control system and is on/off considering the house relays smart systems algorithm. Whenever we need the output to be within a standard range, or wish to make scale conversion, we use post-process on fuzzy controller output signal for energy conservation.

Keywords: Internet of Things, Smart Sustainable Common Home, Fuzzy Logic, Energy Conservation
Article history: Received 2023/10/18; Revised 2024/03/01; Accepted 2024/03/10. Article Type: Research paper

1. Introduction

Iran is one of the countries with significant energy consumption increase, so that now in addition to high energy consumption, the country faces high energy intensity, as well. However, the progress made in the country does not comply with such energy consumption pace. Furthermore, according the statistics, more than one-third of the Iranian energy consumption has been for housing, administrative and commercial sectors, other than production and employment, which demonstrates the need for further focus on the housing sector. Evidently, considering the high population growth (9%) in the 80's, which reached 21 million, now more than 2% of annual construction increase is needed, which indicates building design in a way that in addition to minimize environmental effect, cost-effectiveness shall also be considered to make sufficient energy resources available for integrated country progress. Academically speaking, a building with such features shall be cost-effective and sustainable [1].

Energy consumption has increased 7% p.a. in Iran. Furthermore, more than 98% of the total energy consumption in Iran and around 99% of energy consumption in buildings are supplied through oil and gas resources. Modern energies are used quite limited and dispersed, and only in experimental level. On the other hand, housing and commercial sectors consume more than 40% out of total energy of the country. Buildings energy consumption in Iran is quite higher than many other countries, while inflation and energy price is quite lower, whereas the government offers huge subside for energy. According to a precise economic assessment, capital return term for energy consumption decrease in Iranian buildings is less

than their effective lifetime. Due to the long-term investment return to limit energy consumption in buildings, nobody is interested in this matter in Iran, especially the methods increasing the building prices. Due to low energy price and high building price and non-cost-effectiveness of investment in this sector, using cheap methods to control energy consumption in buildings concerning Iran conditions is suggested [2]. Due to growing trends of building construction industry in the country and sustainable development concept, as well as the importance of paying attention to the future generations, achieving presentation of optimization smart methods for sustainable home in terms of energy based on environmental criteria is needed. Today, the housing has faces fundamental changes in the country and the problems in this field has been more qualitative than quantitative. The occurred phenomena of expediting, making small and making cheap using any methods have resulted the new residential places in the country to lack needed standards and criteria for the sectors relevant to housing. Evidently, in case such trend continues, it may become too late.

As the main interface between outer and inner areas, building walls play an important role to control environmental conditions and providing comfort for the building's residents, and eventually, reducing heating/cooling loads. Using optimized materials for outer walls of building may be considered as one of the easiest and effective ways to reduce building heating/cooling loads, which may result in energy conservation with relatively low expenses. Therefore, smart conservation methods to control and use the buildings are of certain importance.

Upon 1973 energy crisis, the European and developed industrialized countries started conservation and compiling European integrated energy law. Whereas energy conservation, as an investment, may decrease public costs, using modern technologies for building industry has become especially important in developed countries due to high energy consumption in buildings with regular materials. Energy conservation in buildings topic has been addressed as a major need in the country, which shall be focused considering energy consumption in buildings, of which the main part is wasted due to failure to observe technical principles and using industries. Residential buildings are built similarly for different climatic conditions are failed to comply with their environments. Air conditioning systems are still calculated and designed in estimated methods. However, such methods have been waived in modern countries for ages, and we shall start decisively right now, I f we would like to keep the pace with the global system.

Today, buildings are in turn certain types of technology which permanently react to the changing conditions of the environment and adapt to and use them. Evidently, using such materials increases building effective lifetime, and eventually, limits buildings maintenance costs, significantly [3]. Energy consumption growth in Iran is more than triple of the global figure. Energy consumption in our country has been estimated to be more than four times of its global figure. With the current energy consumption pace in the country, in 2025 Iran becomes an importer from and energy exporter and also loses the high energy export incomes [4]. Therefore, the need for energy consumption management is seen as a quite important issue. Correct energy consumption management requires recognition of consumption model, current situation and planning and controlling consumption for conservation and modifying consumption model [5].

According to the statistics and studies, we understand that continuing current pace of energy consumption endangers the country progress and make us deviated from out targets. Therefore, we shall think of a quantitative change in terms of consumption resources and qualitative change in consumption model in all sectors, specially building construction. Sustainable smart houses shall be built to be both nature-friendly and cost-effective.

Many of sustainable architecture rules are not observed in new constructional developments in cities, especially in mild and humid climate and follow traditional constructional using market-available materials. Therefore, most new buildings fail to comply with the sustainable architecture which caused problems to their occupant. Considering high energy consumption in residential buildings, energy conservation and offering design solutions to decrease energy consumption such as a fuzzy smart system for energy conservation is important and necessary. Smart buildings are of modern construction technologies in architecture in which energy conservation and consumption control, limiting energy dissipation, comforting and time and cost effectiveness of building repair and maintenance are highly helped. Using smart technology for building construction and architecture, proper and timely response to environmental and climatic change prevents energy waste and increases building effective lifetime. This process extensively results in an increase in environmental sustainability, which is one of the priorities, principles and targets of sustainable architectural design. Today, smart buildings are low in terms of energy consumption and act as a dynamic and integrated system to make full arrangement among management, system, services and structure. In smart and sustainable buildings design, using environmentally friendly materials increases

building effective lifetime and therefore, effective steps are taken for sustainable architectural design.

In late 20th century, upon development of smart technologies, development of communication networks and internet, development of sensor networks and sensors, extensive efforts and studies started to use such technologies as a means to offer solutions to improve human life. One of the main applications of these technologies was communicating with objects and gaining information through such objects. This paradigm was first offered by Kelvin Ashton through a speech in 1998. In fact, certain solutions were suggested to be used through internet to contract with any object at any time and place, identifying them in the network as well as achieving environmental information and their situation provided new forms of communication among individuals and objects, and event among the objects, which resulted in internet of things, which included objects in addition to individuals and data, as well. Defining objects has been expressed as follows as per European research projects on internet of things: Objects include all active participants in business, information and processes which are able to interact and communicate among them and with the surrounding environment and exchange data and information in sensing environments. Furthermore, they may react to the real world and physical incidents. Objects play an effective role on executive processes and may also develop measures and services with or without direct human involvement. The first architecture was the 3-layer architecture, defined as follows: (1) Perception layer (information); (2) Network layer; (3) Practical layer. This architecture is the basis to introduce other architectures in internet of things [6]. Considering growing trend of Iranian building development industry and sustainable development concept, suggesting the design of fuzzy smart system for smart home energy conservation with smart conservation algorithms is important. Due to certain reasons, including but not limited to variability in different regions variables, the existing design models cannot be considered for all regions of the country.

In this concern, regarding the house air conditioning controlling methods, often a certain parameter is set and/or each are controlled separately in models where a couple of parameters affect system performance. In this article, simultaneous humidity and heat control and its effect on home ventilation have been focused. Furthermore, fuzzy algorithm is used to improve this method. In this article, the prohibited exploration tool has been used to suggest sustainable common home air conditioning system. Therefore, first of all the basic concepts and a brief explanation on the housing system and a review on the relevant controlling methods shall be provided. These have been explained in third part. Ventilation system equations and modelling have been given in results and effect of different parameters of temperature, humidity and light have been explained in these equations. Sustainable buildings modern controlling and using methods are of certain importance. In this concern, regarding the house air conditioning controlling methods, often a certain parameter is set and/or each are controlled separately in models where a couple of parameters affect system performance. In this article, simultaneous humidity and heat control and its effect on home ventilation have been focused. Furthermore, fuzzy algorithm is used to improve this method. In this article, the prohibited exploration tool has been used to suggest sustainable common home air conditioning system. Therefore, first of all the basic concepts and a brief explanation on the housing system and a review on the relevant controlling methods shall be provided. These have been explained in third part. Ventilation system equations and modelling have been given in results and effect of different parameters of temperature, humidity and light have been explained in these equations. In this article, the proposed system algorithm is a fuzzy system that can control the heat of the environment. Due to the fact that the controller of the central system is a fuzzy control, this controller can put the variables that have little dependence together and use the temperature and humidity inputs to adjust the temperature. The proposed system has been able to control the proper accuracy by considering more than a few sensors for each quantity. environmental parameters to do.

2. Study Background and Problem Literature

Smart buildings use the latest technologies in optimization smart methods to provide ideal conditions together with energy conservation in buildings. This system both monitors different parts of building and provides suitable conditions and causes energy conservation, machines efficiency promotion, and added-value concerning the existing facilities in the building through providing simultaneous services. Evidently, this way, the original capital spent on development of this system will be returned through conservations resulted from the same. In this system, the energy is consumed correctly and while the produced energy is protected, the conservation methods are indicated. Controlling and accessing this system at any location inside and outside the building is possible using relevant software through telephone and internet [7].

A) Smart Building

The system existing in smart building provides the occupants with an effective and comforting living environment. These systems act integrated in a smart building and put different objects to be interacted with each other. Smart buildings combine the best ideas, materials, systems and technologies. These elements combine to achieve better performance in sustainable building [8]. Sustainable smart building provides the residents with an effective and comforting living environment. These systems act integrated in a smart building and put different objects to be interacted with each other. Smart buildings combine the best ideas, materials, systems and technologies. This system may be used to delegate the office and controlling tasks of the building to smart management using an integrated computer network [8]. Today, existing of smart buildings is unavoidable. A sustainable smart building shall be able to meet the needs of its users. High performance, energy conservation, comfort and increased building effective lifetime are some of these purposes which are achieved through constructing smart buildings using smart optimization methods. If any work may adapt to facilities and limits considering its needs as any moment, then it may act in an optimized manner with the best cost-effectiveness. Smart materials play a significant role under economic and environmental conditions [9].

B) Smart Architecture

Organic architecture defined by Frank Lloyd Wright as buildings structure adaptation based on placement in the nature, has discussed today in the form of sustainable architecture and its new horizon, smart architecture with smart materials and nanotechnology. Whereas using smart materials achievements in different times and locations may result in different behaviors, materials recognition theories are totally changed. In fact, the materials lose their fixed identities and the architecture shall have no limited definition in terms of location and time, anymore. A sustainable smart building is the buildings which thinks of its own and assesses its needs to meet the same. Smart materials are the first and most effective step in order to have such a building. Some of the major features of smart architecture include dynamism and being active, flexibility, and being environmentally friendly, reactive and responding [10].

Internet of things is defined as the possibility of communication of all objects with each other and the humans together with identifying and discovering them under an integrated network with certain ID, and provides the possibility of communicating anybody at any time and location [11]. This technology includes different objects and technologies such as sensors, machine-to-machine, middleware, big data, cloud processing, and fog computing which work in a global network [12].

Internet of things is a change oriented and changing model, considered in several practical fields, including but not limited to smart homes, smart environment, and remote health care [13]. These practical fields all use internet of things to help the humans to improve health, decrease energy consumption and safety [14]. New environmental conditions and different features of the machines, especially smart systems in sustainable residential buildings caused to especially focus security in this technology and several architectures and platforms are suggested for the same. Furthermore, a major part of the communication among the machines is in machine-to-machine manner, which means that we have no big control on such communication [15]. On the other hand, due to objects ownership as well as the privacy, paying attention to security cautions relating to identifying and discovering, accessibility, access control, privacy and trust shall also be of more importance in smart object topic [16]. Abusing internet of things at smart home may endanger humans/ lives. Therefore, security is a key topic for put this technology into practice which requires extensive studies. Assuring humans lives safety, preventing improper chain of incidents, objects availability, encoding and protection technologies, information confidentiality and integrity, non-deniability, information adaptation and their security levels in different systems, verifying objects and individuals' identities using multiple factors such as passcode, location and biometrics, different models for trust and decentralized identity verification are some of these needs [17]. However, by the increase in development in some of the home appliances with internet connectivity, security and privacy risks are also rising [18]. Five general features including automation, being multi-purpose, compliance, interaction and productivity shall be provided in a smart home, whereas the internet connectivity is highly considered for better and more smart service in smart homes, and that the technologies used in these homes may face challenges and security issues besides several advantages, which are quite probable [18].

Ever increasing progress in smart buildings as well as innovation pace in this field have resulted in a big number of studies to implement different applications [6], e.g. energy management, building management simplification, residents comfort improvement, energy conservation, reactive alarm management, personal security, protecting assets, disturbing events management, etc. For instance, the frameworks of future objects smart buildings control heating and ventilation smartly to change the humans' lives and such a building may rapidly react

to potential problems [7]. One of the main purposes of smart homes is to establish further smart control and security in a house or even in a big building. In fact, using internet of things technology and web and/or mobile applications based on this technology, the machines and devices in a smart home may be under further monitoring and control in the form of objects [19].

One of the efficient methods to decrease energy consumption in the information transfer in internet of things is object clustering method. In clustering, each cluster has a node, namely head cluster, which is in charge of coordinating the network operations and collect data from sensor nodes. Furthermore, head cluster removes excessive and unwanted data packs resulting in a decrease in overhead and infringement. On the other hand, it reduces path finding complexity through minimizing path finding size and number of nodes, and also increases the sustainability clustering mechanism and sensor networks scalability. The other advantage of clustering mechanism is balancing the load which shares the network duties with the member nodes considering battery energy and memory. The most important matter in this concern is to improve energy consumption in data transfer cycle. Most of the communicative and calculative duties shall be completed shortly, to prevent undesired consequences, as internet of things applications are quite time sensitive and vital.

C) Effects of Internet of things on Decreased Electricity and Energy Consumption

Internet connected smart gadget enable the users to prevent uncontrolled electricity consumptions which usually occurs by highly consuming home/office appliances. Those citizens who make their homes smart shall receive a warning on energy dissipation by appliances they cannot even think of. For instance, in case an unused charger cable is connected to the power, your mobile phone receives a warning on useless electricity dissipation, to enable you disconnect it from the power, as soon as possible [20].

D) Smart Buildings as One of the Suitable Solutions to make Energy Consumption Smart

Smart buildings are one of the suitable optimization smart methods to apply energy conservation management. In smart building, cooling equipment is panned based on needs. For instance, such equipment may be programmed to shut down cooling systems when nobody is at the building, and apply needed cooling when they are present based on heat intensity. This way, a proper temperature may be applied. Using building energy management smart systems with correct management prevents any excessive consumption and on the other hand does not harm the residents. Furthermore, using smart equipment in buildings improves safety and effective lifetime of smart building in addition to applying optimized management on resources consumption and dissipation, as by preventing common leaks smartly which endanger the buildings, and through applying necessary shutdowns the damages caused by quake and/or other natural disasters may be decreased and a safe environment may be developed. Therefore, now considering our country situation, using modern technologies in buildings may also be an important step for the environment protection in addition to decreased energy consumption [21].

In the article [22], four data mining models may be considered for internet of things. Multilayer, distributed, networking, and combined technologies data mining models; multilayer data mining model includes four layers: (1) data collection layer; (2) information management layer; (3) event processing layer; (4) data mining services layer/. Internet of things refers to next internet generation which includes trillions of small sensors connected to the internet. This technology is the next revolution after computer and internet revolution. IT is the merging of modern technologies (e.g. sensor networks, RFID technology, mobile communication technologies, integrated computations and IPV6, etc.) and generating development path from next internet generation. Internet of things is the core of smart planet and it is suggested that internet of things produces a high volume of information. For instance, consider a supermarket, where RFID technology has been applied. Unprocessed RFID information format includes the following: location, time and information regarding reading RFID, and normally 18 bytes are needed for information storage. There are around 700000 RFID tags in a supermarket and 12.6 GB unprocessed data is generated per second. Therefore, certain methods shall be conducted for data mining and data analysis regarding internet of things unprocessed information [22].

Internet of things may be a huge flood of information out of different resources. Data mining and valuable information extraction techniques out of data has been one of the fields of interests of the authors. The purpose of data mining in IOT is to extract valuable information out of unprocessed data, and how to extract meaningful information and knowledge from information resulted from IOT. In the article, the relation between big data bases, data mining as well as original unprocessed information is explained. Clustering and labelling the data resulted from IOT may highly help extract meaningful information from big data bases.

KMEANS algorithm is one of the proper tools in this field. Hitting the ground by the elderly is referred as one of the clustering applications in internet of things, and this event may be identified in smart homes. Markov chain is one of the useful tools introduced in the field of internet of things, which may model potential processes. Also, two inner and outer environments have been considered for clustering algorithms. Outer environment example is traffic control, where car's location is estimated using camera PIR sensors and even SMS. The example of data resulted from inner sensors is health field. The next item out of data mining in internet of things examined in this article is the model identification topic, studied as one of the other branches of data mining. In this field, we are looking for identifying model among the data, and one of its applications is identifying purchase model at the shop, which may be achieved through RFID tags [23].

In article [24] individuals' care and identification in different environments using body sensors has been studied. Monitoring individuals and examining health condition have been studies in this article.

Sensor data format is as per the following parts:

Health data	MAC-Identification ID-Battery	User ID

Health data may be related to one's heartbeat as well as respiration and blood circulation, for which information combination in different time intervals shall be made. Using health data, categorization and eventually one's health identification are conducted [24]. Distributed on database and implementation through cloud are studied in the article, and it has been demonstrated, accordingly. A data mining method on the distributed database has been suggested based on player model. The suggested method has been extended on distributed databases and implemented based on player model and internet of things. The suggested method breaks the database into some smaller databases and simultaneously, data mining is conducted at data centres as well as entire database.

Furthermore, some of the libraries on database have been introduced later in the article [25]. In the article, transportation database has been focused and it has been tried to use data mining on internet of things regarding occurrence of road accidents. The format of the studies data in the article is as per fig. 2.

In article [26], RFID tags have been used to identify moving cars, for which information is collected. Car's identification system, tags and reading and antennas have been studies in this article. Two solutions have been suggested in the present article for the issue of identifying together with uncertainty: reliable information transfer protocol as well as disclosure algorithms, and eventually model validation has been conducted in fig.3.

In article [27], a suitable tool has been given to design traffic control using internet of things and a suitable system to design traffic control has been suggested in fig.4.

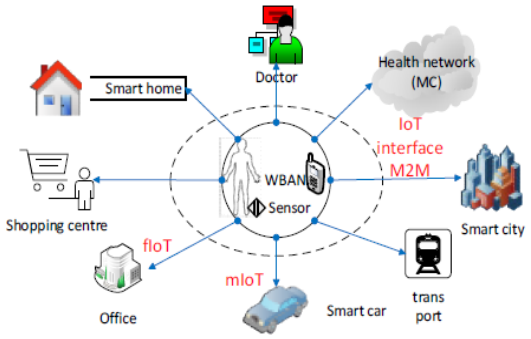

Fig. 1. Studying the general condition in different environments [3]

Fig. 2. Extracting Information from Unprocessed Data

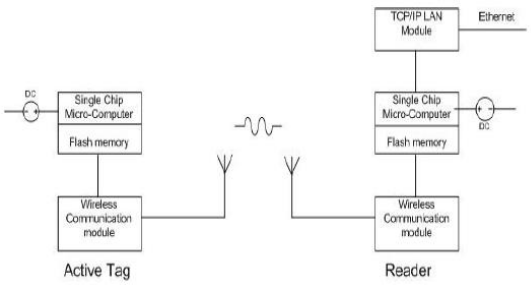

Fig. 3. Suggested Electronic Circuit [5]

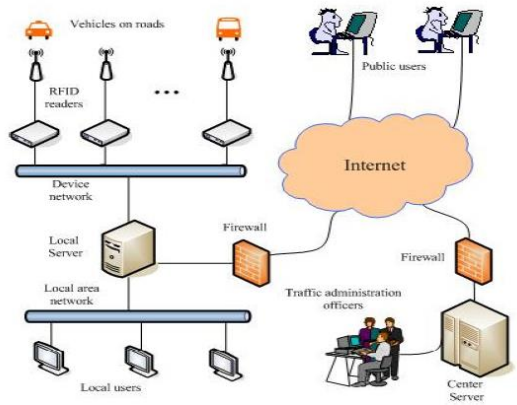

Fig. 4. Suggested Arrangement and Algorithm for Traffic Control [5, 6]

In article [27] a method for traffic accidents prioritization has been suggested, so that the higher priority accidents may have right to pass. In this article, a proper method to schedule based on prioritized right to pass has been studied in fig 5. Suggested system for traffic management is as fig.6. In article [28], GPS tool has been used as a means to try to design traffic control system. In order to do so, a cheap, Wi-Fi based system has been suggested with the duty of smart monitoring and controlling traffic based on obstacle measuring sensors and leader sensor is one of the sensors embedded on the car used for traffic identification. (fig.7). The system tries to identify the traffic using wireless sensor networks and obstacle in road and street areas is identified using existing sensors, including laser.
In article [25] a method has been used to control traffic and reduce air pollution by using road side sensors, and it has been tried to predict the traffic using GPS. (fig.8).

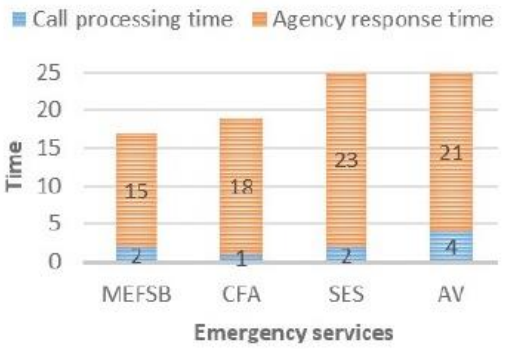

Fig. 5. Accidents Scheduling and Responding Time [6]

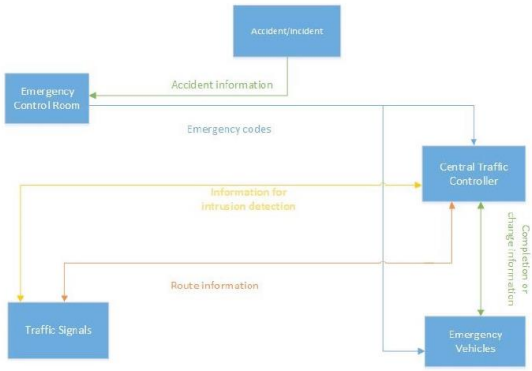

Fig. 6. Traffic Control Management System [6]

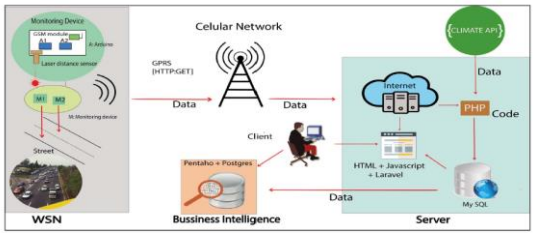

Fig. 7. Traffic Control Sensors Structure [7]

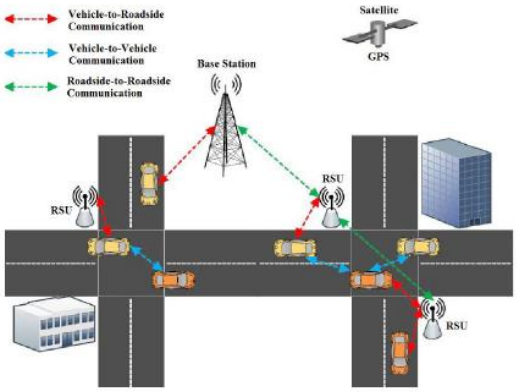

Fig. 8. Traffic Control Sensors Structure [8]

E) Energy Consumption in Iran

Considering growing energy consumption in Iran, the present research sees the necessity of studying energy dissipation through building walls as a means to reduce energy intensity. According to the following table, which shows original energy consumption and average energy consumption in domestic sector, energy consumption status in Iranian transportation industry is quite high which is directly related to embedded energy [29].

F) Energy Consumption Reduction in Residential Building

Shoaybi and Torkashvand have suggested solutions to reduce energy consumption in building. These solutions are categorized into two main groups: architectural and technical solutions [30].

Table.1.
Original Energy Consumption in Domestic Sector, in Iran and some other countries

Sector	***Domestic***		***TransporT***		***Domestic***		***Transport***
Country/ Region		***Industry***		***Total***	***%***	***Industry %***	***%***
USA	1903	781	4195	6881	26.67	11.38	60.99
Japan	598	412	575	1584	37.76	26.04	36.24
UK	155	605	315	107	14.34	56.33	29.31
Germany	268	171	362	805	33.59	21.22	45.14
South Korea	151	173	206	534	28.87	32.26	38.88
Turkey	55	52	112	234	26	23.77	50.29
The world	7168	6475	15379	29028	24.70	22.35	52.94
Iran	360	254	283	283	40.13	28.32	31.54

Table.2.
Average Per Capita Domestic Energy Consumption in Iran and some other countries

Country	***USA***	***Japan***	***UK***	***Germany***	***South Korea***	***Turkey***	***The world***	***Iran***
Consumption Intensity	0.35	0.25	0.22	0.33	0.44	0.51	0.47	1.02

Table.3.
Average Building Energy Consumption per Square Meters in Iran and some other countries

Country	***USA***	***Japan***	***UK***	***Germany***	***South Korea***	***Turkey***	***The world***	***Iran***
Consumption intensity	135	94	69	183	165	174	171	401

Ghaffari, Jabbari, et al. examined the weaknesses of Tehran City construction development industry and understood the weaknesses in building design and construction phase, suggested methods to decrease building energy consumption. In order to do so, 20 different types of buildings were designed and modelled suing energy simulator software, and their cooling/heating energy consumptions were calculated [31].

Regarding walls optimization, Pourdeihimi and Gosili studied outer walls in cold climate local architecture to study the role of building outer wall in heating energy dissipation and transfer [32].

Torabi in the article of studying the effect of higher efficient building shell on change of costs and consumed energy of building concluded that the building heating load is sharply decreased by using such shells and eventually, small devices to meet such load are needed and the original price to energy consumption annual cost decrease ratio resulted from using them decreases. In order to do so, either the fuel price shall be increased or the cost of using such walls shall be decreased [33].

Recently, the low-energy consuming buildings have more been interested. In this concern, most of the studies focused on construction techniques, building architecture as well as energy alternative resources. In this regard, energy consumptions details in residential sector is highly interacted and sophisticated. Conceptual models shall be carefully studied to assess the technological, economic effects and efficiency of renewable energies suitable for domestic use [34].

In the paper [35], some studies would be analysed to identify the technical advances that have laid the base for a better future. This paper also presents the challenges that confront the real-life scenarios and proposes a guideline for the proposed solutions. It can be concluded that various machine to machine and advanced technologies can enable a building to respond intelligently to achieve energy efficiency.

This article[36] presents a model for predicting indoor air quality, considering the importance of smart buildings and the need to provide new solutions for their smart management. Data are collected from this project's control and monitoring system on different days and hours, and air quality is performed using a neural network of the radial base function. The neural network of the radial base function has three inputs: temperature, air humidity, and carbon dioxide. The network output includes volatile organic compounds in the air.

The purpose of the research [37], among others, is how to monitor the use of electrical energy in the household by utilizing IoT and connected to the Android application to make monitoring easier. The contribution given by the researcher is how to combine microcontroller hardware, internet and android applications so that they can support the use of smart homes at home. Research Methodology includes data collection, needs analysis, program development, tool design, testing

In the paper [38], it proposes two IoT based systems in the context of Smart homes: qToggle for multiple home automation, and MotionEyeOS, a video surveillance OS for single-board computers. Most qToggle devices are based on ESP8266/ESP8285 chips or on Raspberry Pi boards and smart sensors, while MotionEye uses Raspberry Pi boards.

3. Expert Systems

As a general definition, expert systems are computer programs simulating an expert way of thinking in a certain field. In fact, this software identifies the logical algorithms used by any expert to decide, and then decide like humans based on such models. [26].

One of the purposes of artificial intelligence is to understand human intelligence through simulating it using computer programs. However, evidently, “intelligence” may be extended to several understanding-based skills, such as the ability to decide, learning and understanding language, therefore, it is seen as a general term. Expert systems are one of the main and important viewpoints out of the early problems solving works and importance of certain knowledge based on the relevant field. [26]

Expert systems are a sub branch of artificial intelligence which uses knowledge and inference to solve complex problems requiring human expertise and experience [27].

Expert system includes two main pillars of knowledge based and inferential engine. Knowledge base include if-then rule and inferential engine uses post-go and pre-go exploration methods for inference and fuzzy expert system is generated by converting knowledge base from definite to fuzzy state. An expert system is a program which tries to imitate a human expert in using inference methods for a certain framework of knowledge. Expert systems have been considered as a field of artificial intelligence, as mainly their problem solving is based on mental discoveries. Expert systems differ in terms of processing knowledge using common programs. This knowledge is displayed in a computer as rules. One of the advantages of expert systems is that they may be used besides human experts, resulting in a decision based on human expertise and machine accuracy. This technology is also commercially profitable for the developers. Furthermore, expert systems have the following advantages:

Increasing Accessibility: many experiences are provided by computer and simply put, an expert system is mass production of experiences.

- Multiple Experiences: An expert system may be the collection of experiences and awareness of several experts.
- Reducing Cost: Cost of gaining experience for the user decreases significantly.
- Reduce Risk: Expert system may also be used in environments which may be harsh and dangerous for humans.
- Permanency: Expert systems are permanent and sustainable; in other words, they do not die unlike humans and are eternal.
- Explanation Power: An expert system may explain the path and reasoning phases resulted in conclusion. However, experts may not conduct such action upon decision making due to a variety of reasons (tiredness, lack of tendency, etc.). Such ability improves your trust in decision correctness.
- Easy knowledge transfer: One of the most important advantages of expert system is the easiness of its transfer to various geographical locations. This matters to development of countries who cannot afford expert knowledge.

On the other hand, using expert systems face certain limitations. For instance, these systems have no feelings with respect to what they do. Such systems may not extend their expertise to wide ranges, as they have been designed to be single-purpose and their knowledge base has been originated from that field experts and is therefore, limited.

In this article, a fuzzy system with 6 inputs and one output is proposed. Three inputs are considered as temperature inputs and three other inputs as humidity inputs respectively. and heater activation output that sets the heater relay. With the help of fuzzy rules, the output of the system is adjusted and finally temperature and humidity control is done with less time and higher accuracy.

4. Fuzzy Logic

Fuzzy Logic is a certain type of logic to replace simpler machine models by variable conclusion methods in human's mind. Any type of reality expression is not a series of true or false. Their reality is something between full correct and full wrong. Something between one and zero, i.e. a multi-value and/or gray concept. Fuzzy is then something between black and white, i.e. gray. "Binary" which sees everything only as black and white, yes and no, zero and one is on the other side. This logic is within 0 and 1 interval and discusses of the value of a member belonging to a series avoiding abstracts (only zero and one). Fuzzy logic is a method to implement human inference and inexact or approximate reasoning. Fuzzy reasoning enables the human to reason and decision under uncertain and ambiguous conditions.

5. Research Methodology

Prior to building energy simulation, certain information shall be obtained on building climatic conditions, building design method, ventilation system and its equipment and building control method. Building outdoor climatic conditions is an important part of the main data and the best state is that the data is prepared for a month on an hourly basis. Usually, 10 to 13 climatic parameters are needed for energy simulation in the building, e.g. sun radiation, temperature, humidity, wind velocity and its direction, atmospheric pressure, etc. This data is usually reported annually.

On the previous study of the author, 9 different scenarios have been used to study electricity and gas energy consumption in the studied building in Sari City. These scenarios include using different materials to meet the relevant target. A 5-floor building, including 20 flats, were modeled using Design Builder software. The studied scenarios include using the following materials: (1) brick block; (2) cement block with granule; (3) Fume cement block; (4) wallcrete block; (5) porous concrete block; (6) aqua panel; (7) 3D panel; (8) ICF; (9) reinforced concrete wall. For all foregoing 9 scenarios electricity and gas energies consumptions have separately been studied and the results showed that electricity consumption for Sari City would be minimum under cement block and granule scenario, followed by ICF and 3D panel scenarios. Maximum annual electricity consumption is also related to fume cement block with a big distance from other scenarios. Relating to annual consumable gas for Sari City, fume cement block and cement block with granule had maximum and minimum consumptions, respectively in fig.9 ,fig.10 and fig.11.

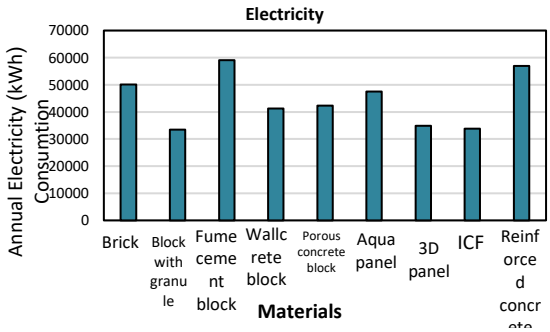

Fig. 9. Annual Electrical Energy Consumption, studied Scenarios for Sari City, (k/Wh)

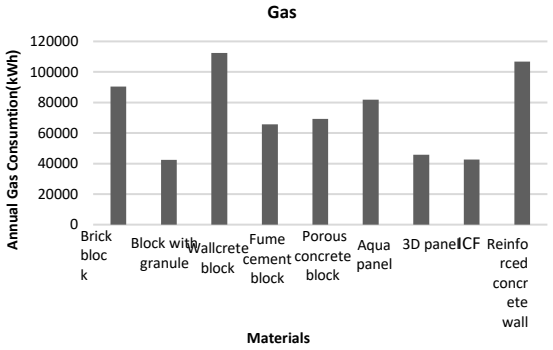

Fig. 10. Annual Gas Energy Consumption, studied Scenarios for Sari City, (k/Wh)

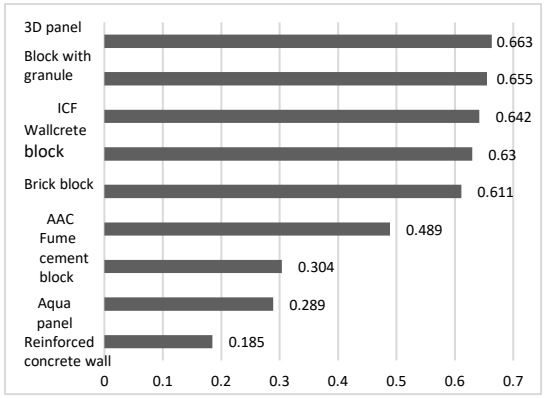

Fig. 11. Final Options Ranking by applying Cost and Reusing Materials together with Embedded Energy Value

In this study, energy conservation and energy reduction through building walls have been studied. According to author's studies, materials used in building are quite effective in reducing building consumption in building. Considering different climatic conditions in the country, correct studying to use the proper materials and walls in residential buildings may play an important role in energy conservation in buildings. Generally speaking, type of used wall is one of the most important and effective factors to decrease energy consumption in buildings. Therefore, using cement block with granule instead of fume cement block shall result in a decrease in energy consumption up to 47% in buildings and we shall see the effect of energy conservation in building. Among the studied wall scenarios, and according to data resulted from Design Builder software, outer wall with cement block plus granule is the most suitable system. Furthermore, wall with gas concrete blocks is ranked second. However, according to the experts (cost and reuse) as well as materials embedded energy level (during building life cycle) together with electricity and gas energy dissipation in different scenarios, the criteria were weighed using AHP technique and eventually using TOPSIS technique, 3D panel is the best materials, followed by ICF, cement block with granule, wallcrete block, brick block, porous cement block, fume cement block, aqua panel and reinforced concrete wall were suggested, respectively, as the bet type of materials to be used for buildings wall in mild and humid climate.

In this part, we study the suggested method to improve smart sustainable home control (built by 9 presented scenarios). Heat and humidity were the used sensors, with the duty of monitoring smart home. In this article, we plan to suggest a method to control the smart homes relay, smartly. Sensor's data is entered into the home smart control system and considering smart systems algorithm, the home relays are on/off. Whenever we need to have the output within a standards range, or we would like to convert scale, we used fuzzy controller on output single after processing. The important point in a fuzzy system structure, as also seen in fig. 12, is that the output and input are always definite numbers.

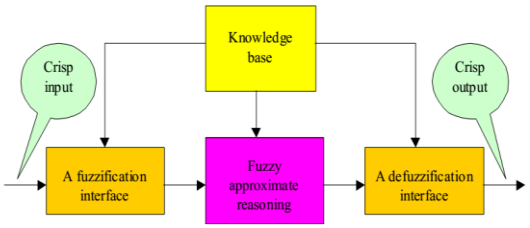

Fig. 12. Definite Output and Input in Fuzzy System Structure

Most linear and non-linear control solutions during past decades are based on accurate mathematical models. These systems are often described by older mathematical relations with difficulty. Therefore, this plan may not result in satisfactory solutions. FLC behaviour is easily understood by a specialist and is knowledge expressed using lingual rules.

Whereas the non-linear systems control issue is complex as the systemic methods are not suitable idea to find sustainable conditions and assurance of strong performance, therefore, using fuzzy control is one of the techniques relating this group of systems. By presenting fuzzy logic as a new model in mathematics, fuzzy controller was also developed in the same logic. Fuzzy controllers' structure is generally classified as follows:

– Type 1 controller (Mamadani controller)
– Type II controller (Takagi Sogno controller)

Type I fuzzy systems structure may vary considering fuzzy making, non-fuzzy making, and inference engine and selecting type of operand. Type I fuzzy systems have shown their ability in several applications. However, type I fuzzy systems

are not suitable in modeling and minimizing uncertainty. Whereas in type I fuzzy systems, there is unique membership level per input, therefore, one of the disadvantages of type I fuzzy systems is in modeling and reducing uncertainty effect.

One of the other important types of fuzzy control systems is Takagi Sogno or type II fuzzy control system. Unlike Mamadni fuzzy control, in this type the controlled system equations shall fully be known and the output is expressed as a function. In Takagi Sogno fuzzy control systems design, good efficiency is seen for non-linear control systems.

A) Data Pre-processing

The need to identify fuzzy controller in non-linear systems, and especially, applying it in ventilation system in this article, needs to learn about its performance. Therefore, in this part, after presenting basic definitions of fuzzy systems, remarks on manner of designing this type of controller has been given. Input data of sensors face uncertainty and noise. In real world, sensors measurement data is not accurate and has noise. The first step is reducing noise of sensors measurements. Several methods have been suggested in order to do so to decrease sensors measurement error [25, 26]. The suggested method in this article is to use measures specimens' average based on fig.13. In this article, all ten previous specimens are averaged with real time value, and recorded as real time. This way, the sensors measurement error variance is limited and measurement noise is significantly reduced. In figs. 14 and 15, the error variance decrease has been given with suggested method. Averaging is a integration method when the integrating circuits feature includes low speed and reduced noise, i.e. in case of high changes in sensor value, integration does not result in a high change in real time output value, and be in proportion to other real time values. It has been assumed in smart home that there are three temperature sensors and three humidity sensors. Information controlling system received from 6 sensors is received and finally relays relating to humidity and temperature are activated. There are two relays relating to temperature in smart home to keep the temperature stable, which are connected to heater or cooler, as the case may be. Furthermore, there as two relays for humidity increase/decrease. There is risk of error in reading sensors. The three temperature sensors result in a decrease in risk of error. This is also the case for humidity sensors.

B) Designing Controller Suggested System

The suggested fuzzy system receives temperature and humidity values and then, considering the fuzzy system measured values, decides to shut down or connect the temperature relay. Heater is turned on in case the house temperature is less than the reference temperature, while cooler is turned on if temperature is more than the reference interval. On the other hand, fan is turned on if the air humidity is more than the permitted figure and humidifier relay is turned on, otherwise. The suggested algorithm acts in decision making layer. Higher number of sensors is due to the risk of error in other sensors.

The suggested fuzzy system is composed of three parts: input, inference system and non-fuzzy making. In input of fuzzy system, there are sensors input, in a way that the sensors values are entered into the fuzzy system and the fuzzy system conducts inference in the next phase using rules, whenever it is on fuzzy system inputs and finally, relevant relays which are fuzzy system output is activated. Fuzzy system is of Takagi Sogno type, whose output may be a 4-bit figure, indicating connection or disconnection of 4 different relays. Results have been shown in fig.16 to fig.23.

Fuzzy system is not considered in below conditions:

- If the ambient temperature is low and the humidity is low, the heater is activated in a large amount.
- If the ambient temperature is low and the humidity is average, the heater will be activated at an average value.
- If the ambient temperature is low and the humidity is high, the heater will be activated at an average value.
- If the ambient temperature is high and the humidity is low, the heater will not activate.
- If the ambient temperature is high and the humidity is moderate, the heater will not activate.
- If the ambient temperature is high and the humidity is high, the heater will not activate.
- If the ambient temperature is normal and the humidity is low, the heater will not activate.
- If the ambient temperature is normal and the humidity is moderate, the heater does not activate.
- If the ambient temperature is normal and the humidity is high, the heater will be activated in a small amount.

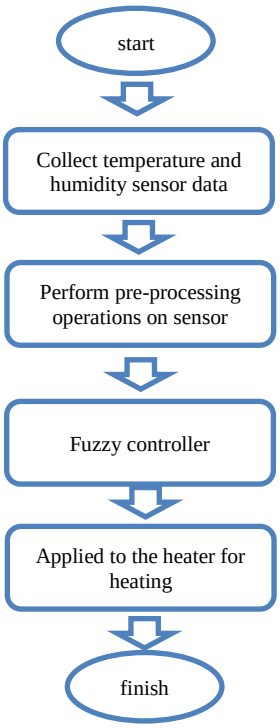

Fig. 13. Flowchart of proposed method

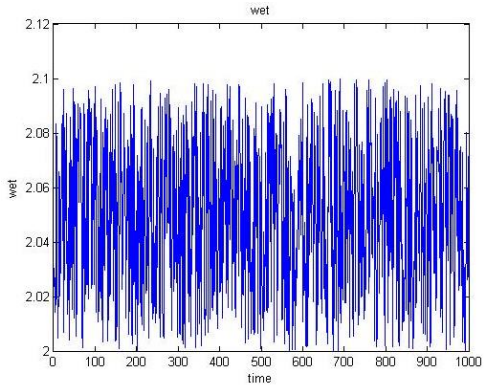

Fig. 14. Humidity measured with 1% Variance

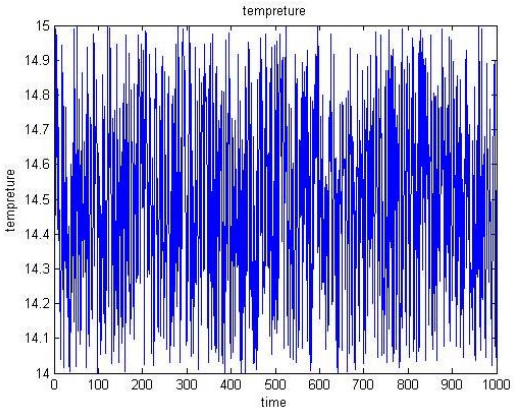

Fig. 15. Temperature measured with 1% Variance

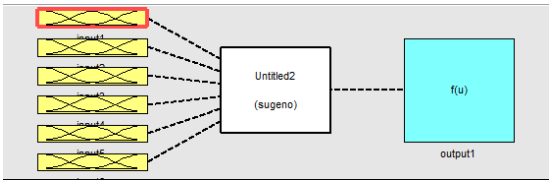

Fig. 16. Fuzzy Model with Six Inputs from Temperature and Humidity Sensors

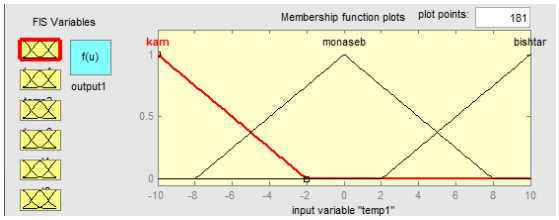

Fig. 17. Functions of belonging of Fuzzy System Temperature measured Value by 1st Temperature Sensor

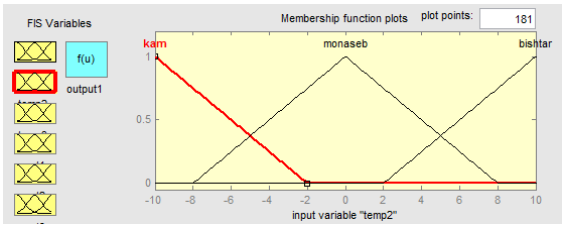

Fig. 18. Functions of belonging of Fuzzy System Temperature measured Value by 2nd Temperature Sensor

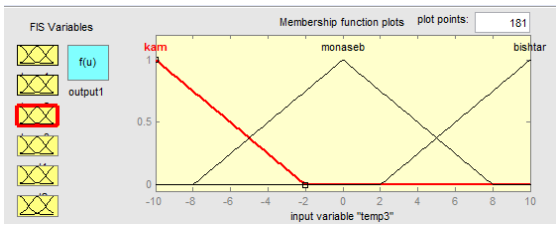

Fig. 19. Functions of belonging of Fuzzy System Temperature measured Value by rd Temperature Sensor

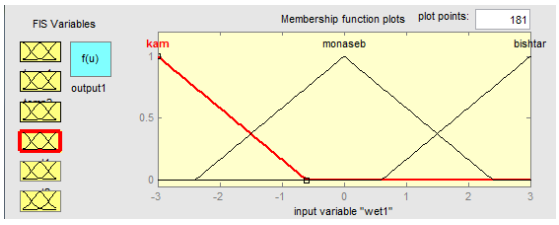

Fig. 20. Functions of belonging of Fuzzy System Humidity measured Value by 1st Humidity Sensor

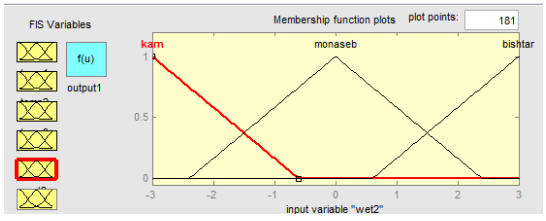

Fig. 21. Functions of belonging of Fuzzy System Humidity measured Value by 2nd Humidity Sensor

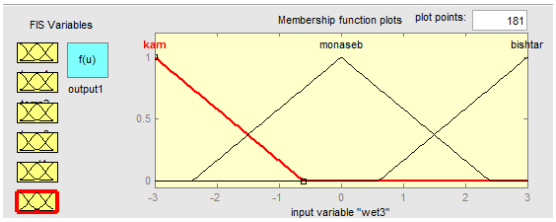

Fig. 22. Functions of belonging of Fuzzy System Humidity measured Value by 3rd Humidity Sensor

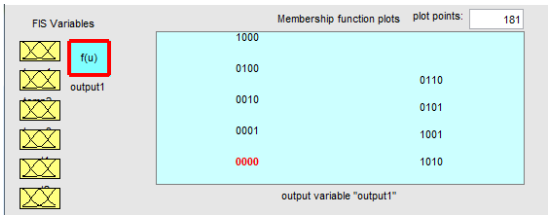

Fig. 23. Functions of belonging Fuzzy System Output

6. Research Results

Simulation has been considered for smart sustainable home using suggested fuzzy system. Simulation has been measured for multiple reference inputs. Room temperature with first degree differential equation complies with on reference input. Eventually, the system output has been shown in the following figure for step input. Fuzzy controller and PID may be compared in table 4. The system step response to control frequency has been shown in the fig.24.

7. Conclusion

The suggested method is focused on smart home control. The used sensors are heat and humidity sensors with the duty of monitoring smart home. In this article we plan to suggest optimized smart method to control smart sustainable common home relays smartly. The sensors data is entered into the sustainable common home smart control system and is on/off considering the house relays smart systems algorithm. Whenever we need the output to be within a standard range, or wish to make scale conversion, we use post-process on fuzzy controller output signal for energy conservation.

The suggested algorithm to control smart home relays was studied using fuzzy system. In this article, first of all a pre-processing method was considered for the signals resulted from different sensors to decrease error variance and in the next step comparing between PID and fuzzy control methods was conducted using fuzzy control. Improving smart home control using fuzzy system highly helps control of home temperature and humidity and may effectively meet a high number of sensors to control the home, smartly.

Table.4.
Values resulted from PID and Fuzzy Controller

	Over shoot	*Tr*	*Ts*
PID	28%	34S	50S
Fuzzy	0.1%	33S	45S

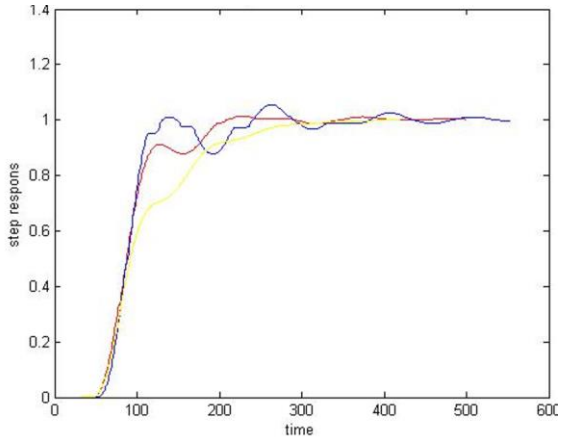

Fig. 24. Output Relays Response to Step Response

Acknowledgment

The authors gratefully acknowledge Dr. Tanhayi (Professor of Physics Department, Islamic Azad University, Tehran, Iran) for providing us technical and scientific supports.

References

[1] Ardebili, Sousan, what is green building, bank and economy, February 2020 vol. 104, pp 57-58

[2] Khorrami, Mohammad, Moaveni, Soheila, Meshkat Razavi, Hesamedin, the necessity to construct green building in Iran and comparing it with regular modern buildings. Esfahan Province Construction Engineering Organization magazine, sustainable building special issue, 2013

[3] Ghobadian, Vahid, Feizmahdavi, M., climatic design theoretical and practical principles of energy application in building, Tehran University Press, 2003

[4] Shah Hosseini, Mohammadali, designing energy policymaking model in perspective with dynamic systems approach, 2009, PhD dissertation, University of Tehran, faculty of management

[5] Khademi, Zare, Hassan and Akhavan Akharin, suggesting a consolidated model to predict load peak and establish supply/demand balance of electrical energy with multiple purposes, 24th international conference on electricity, Tehran, Iran, 2009

[6] Bin, S., Yuan, L., and Xiaoyi, W.: "Research on data mining model for the internet of things", in Editor (Ed.) ^(Eds.):" Book research on data minin models for the internet of things", IEEE, edn., 2010, pp. 127-132

[7] Najafimoti, Mansour, (2007), smart buildings, Abadi Magazine, 13th season, vol. 36

[8] Thabit Al-Baldawim, 2015, Application of smart materials in the interior design of smart houses civil and environmental research, No. 2, (Thabit 2015)

[9] Marz Herman, Hansman, Thomas (2019), building management systems, translated by Seifollah niknami and Fatemeh Ebrahimi, 1st Ed., Tehran, Yazda Press

[10] Afshari Basir, Nafiseh, Afshari Basir, Mohammadreza, smart buildings, a step towards modern technology in

building, 2nd international conference on architecture and structure, University of Tehran (Afshari Basir, 9: 2011)

[11] J. Zheng, C.D.S.R. Bisdikian, H. Mouftah, The internet of things, IEEE Communications Magazine, 49(11) (2011) 30-31

[12] A. Al-Fuqaha, M. Guizani, M. Mohammadi, M. Aledhari, M. Ayyash. Internet of Things: A survey on enabling technologies, protocols, and applications

[13] A.K. Sangaiah, G. Li, A joint resource aware and medical data security framework for wearable healthcare systems, future generation computer systems, 95 (2019) 382- 391

[14] D. Vinodham, A.Vinnarasi, IOT Based Smart Home, International Journal of Engineering and Innovative Technology (IJEIT), 10 (2016)

[15] M. O'Neil, Insecurity by design: Today's IOT device security problem, engineering 21(1) (2016) 48-49

[16] Q. Jing, A.V. Vasilakos, J. Wan, L. Lu, D. Qiu, Security of the Internet of Things: perspectives and challenges, wireless networks, 20(8) (2014) 2481-2501

[17] E. Nimmermark, A. Larsson, Comparison of IOT frameworkls for the smart home, (2016)

[18] G. Lobaccaro, S. Carlucci, E. Loftstrom, A review of systems and technologies for smart homes and smart grids, energies, 9(5) (2016) 348

[19] C.L. Stergiou, K.E. Psannis, B.B. Gupta, "IOT big data secure management in the fog over 6G wireless network", IEEE Internet of Things J., 2020

[20] Moazzen, Mohammad, Hossein Mahalleh, Reza, Alirezapour, Bahram, 2018, principles and fundamentals of internet of things, Gilan Press, Rasht

[21] Sarabadani, Ali, Aslani, Mohamamdreza, 2018, internet of things applications in today's world

[22] Bin, S., Yuan, L. and Xiaoyi, W.: "Research on data mining models for the internet of things" n Editor (Ed.)^(Eds.):" Book research on data mining models for the internet of things" (IEEE, 2010, edn.), pp. 127-132

[23] Tsai, C.-W., Lai, C.-F., Chiang, M.-C., and Yang, L.T.: "Data mining for internet of things: a survey", IEEE Communications Surveys and Tutorials, 2014, 16, (1), pp. 77-97

[24] 3-Kang, J.J., Adibi, S., Larkin, H., and Luan, T.: "Predictive data mining for converged internet of things: A mobile health perspective" (IEEE, 2015, edn.), pp. 5-10

[25] Kholod, I., Kuprianov, M., and Petukhov, I.; "Distributed data mining based on actors for internet of things", in Editor (Ed.)^(Eds): "Book Distributed data mining based on actors for internet of things" (IEEE, 2016, edn.), pp. 480-484

[26] Yu, M., Zhang, D., Cheng, Y., and Wang, M.: "An RFID electronic tag based automatic vehicle identification system for traffic IOT applications", in Editor (Ed.)^(Eds): "Book Distributed data mining based on actors for internet of things" (IEEE, 2016, edn.), pp. 4197-4192

[27] Chowdhury, A.; priority based secured traffic management system for emergency vehicle using IOT, in Editor (Ed.)^(Eds): "Book priority based on secured traffic management system for emergency vehicle using IOT" (IEEE, 2017, edn.), pp. 1-6

[28] 7-Nugra, H., Abad, A., Fuertes, W., Galarraga, F., Aules, H., Villacis, C., and Toulkeridis, T.: "A Low-cost IOT application for the urban traffic vehicles, based on wireless sensors using GSM technology", in Editor (Ed.)^(Eds): "Book a low-cost IOT application for the urban traffic of vehicles, based on wireless sensors using GSM application for the urban traffic of vehicles, based on wireless sensors using GSM technology" (IEEE, 2017, edn.), pp. 161-169

[29] Lotfi, Sedigheh, Kheirkhah Zoleikha, qualitative and quantitative study and required housing prediction (case study: 2021 horizon for Sari City), geography and urban planning, Zagros perspectice, 4th year, vol. 12, summer 1

[30] Shoaybi, Hoda, Torkashv and, Abalou, 2014, suggesting architectural solutions to decrease energy consumption in building design, 4th national conference on health, environment and sustainable development, Bandar Abbas, Islamic Azad University, Bandar Abbas Branch

[31] Ghafari Jabari, Shahla, Ghafari Jabari, Shiva, Sal, Elham, 2013, studying housing design solutions for energy conservation of Tehran City, international conference on civil engineering, architecture and urban sustainable development, Tehran, Iran

[32] Pourdeihimi, Shahram, Gosili, Bahram, studying heating IDs of building outer shelter walls, case study: Ardebil rural regions, rural housing and environment, vol. 150, 2015, pp. 53-70

[33] Torabi, Fatemeh, 2013, studying the effect of walls with high heating efficiency in changing costs and building consumable energy, 2nd national conference on climate, building and energy conservation, with sustainable development approach

[34] Aydinalp M., Ugursal VI, Fung A., modeling of appliance, lighting, and space cooling energy consumptions in the residential sector using neural networks, applied energy 2012, pp 87-110

[35] Tatari, M., et al., Review of Smart Building Management System, in ICT Systems and Sustainability. 2022, Springer. p. 167-176.

[36] Majdi, A., et al., A novel method for Indoor Air Quality Control of Smart Homes using a Machine learning model. Advances in Engineering Software, 2022. 173: p. 103253.

[37] Iskandar, D., et al., Design and Build Internet of Things Smart Home for Android Based Electronic Equipment Management System. Jurnal Sisfokom (Sistem Informasi dan Komputer), 2022. 11(1): p. 66-72.

[38] Stolojescu-Crisan, C., C. Crisan, and B.-P. Butunoi, Access control and surveillance in a smart home. High-Confidence Computing, 2022. 2(1): p. 100036.