Intelligent Microwave and PIR Sensor System for Energy Efficiency in Buildings

M.F. Jamburi , F. Sulaiman, *Member, IEEE* and A. Ahmad

***Abstract*—A lot of an electrical energy is wasted everyday due to human attitudes. This paper introduces an alternative way of saving electrical energy by using an intelligent method that have been designed suitable for application in houses and offices. Generally, the system is based on a sensor as a supervisory control in order to organize the electrical energy in houses or room intelligently. In this project fuzzy logic is introduced as a controller for the system. A fuzzy logic controller will make a decision before sending a signal to an actuator either switching on or off the electrical energy. An electrical energy is automatically turned on since the sensor detect the present of human in form of microwave motion and thermal radiation [8]. On the other hand, electrical energy is automatically turned off if there is no human present around the area that it covers. Therefore, the purpose of this project is to effectively control artificial electrical appliances in a smart way for energy saving and energy efficiency in rooms, houses and offices**

***Index Terms*— fuzzy logic controller, microwave and passive infra-red (PIR) sensor, energy savings**

I. INTRODUCTION

CONVENTIONAL controllers cannot provide adequate control for systems that have time-varying parameters, unknown structures and multiple objects [1;2] Previously numerous systems with such characteristics are controlled by humans. There have been several success stories in the construction of automated controllers based on human expertise, notably using fuzzy controllers. Fuzzy rule-based control systems are similar to expert systems in that the rules embody human expert knowledge about the control operation that is being mechanized [3]. In such a fuzzy system, more than one rule can be fired and thus, more than one control action can be recommended [1].

Electrical energy can be controlled automatically. In fact, it will help the user to save on electrical energy and expenses based on its intelligence. The user did not need to worry anymore if forgotten to turn off the lighting or other electrical appliances before leaving a room because with this intelligent system it can be solved easily. The buildings with no automatic control of artificial lighting, the user need to switch on or off the lighting and other electrical appliances manually.

Basically, such a smart controller does a measurement of the present of a human in certain area that it's covered by taking into consideration of human movement and thermal radiation. The controller adjusts an electrical energy at a requested level as desired. Some improvement can be added to make the system more intelligent by distinguishing the presence or not presence of a human and introducing the priority on sensor detection. This paper elaborates on the fundamental concepts about new control parameter and algorithm for electrical energy control system such as smart fuzzy control for automatic lighting and electrical appliances for energy efficiency application. This design is based on the presence of human by movement in conjunction with

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thermal radiation that is needed to reach real energy savings in many buildings.

II. METHODOLOGY

A. Fuzzy logic controller

This project applies the intelligent lighting system for application on many building in Malaysia in a smart way for electrical energy saving and energy efficiency by using fuzzy controller. Fuzzy control theory specified ways to combine a collection of recommended actions to obtain a single action [4].

A fuzzy controller properly consists of:

a. Linguistic variable
b. Membership function (fuzzification)
c. A rule based
d. A fuzzy interpreter
e. A defuzzification function

The linguistic variable of the system are approximate terms describing measurement on the system parameters. Membership functions specified the degree of membership of the measurement in the fuzzy concept represented by a linguistic variable [5]

The rule base is a collection of rules that collectively specify the controller. The rule based interpreter takes the fuzzy description of a process state and determines to what degree the antecedent of each rule matches the fuzzy representation of process state [1; 2]. The crisp state might be fuzzified to more than one corresponding fuzzy process state.

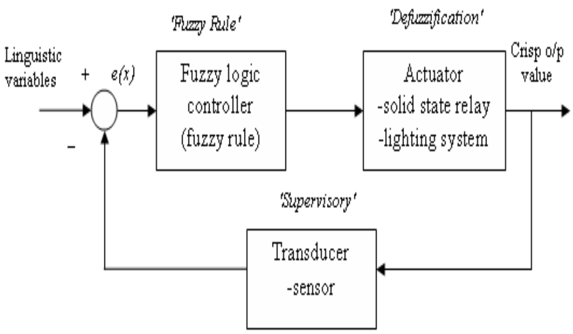

Fig. 1: Block Diagram of Fuzzy Control System

The operation of the fuzzy controller can be summarized in the following list of steps:

-- First, convert one or more crisp reading into fuzzy value using membership function states.

-- Second, determine the degree to which each rule in the base applies for each of these fuzzy states. According to this degree, the fuzzy control system action specified as the consequent of each rule.

-- Third, by the de-fuzzification process applied to the various recommended fuzzy control actions, compute the number that represents the corresponding crisp control action.

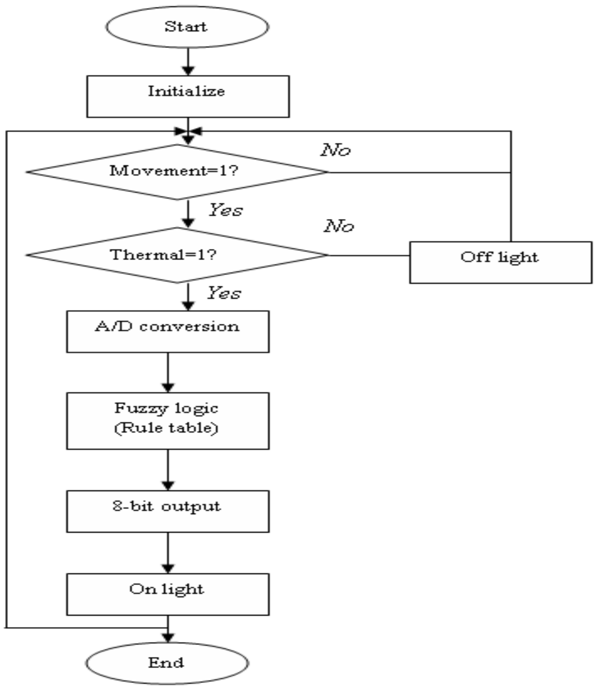

Fig. 2: Flow Chart of Intelligent Lighting Control System

B. Microwave and PIR sensor

Sensor is a device that has the ability to sense the fundamental physical variables [6;7].. A sensor can sense the variable as well as to what degree it's present. Sensor is able to recognize the condition and situation of the process and sending the signal for determined and evaluated to achieve the desired output. [6].

In part of the sensor there is some specification to make the sensor more sensitive and would be functioning based on the area it covers. The sensor or detector used in this project is combination of microwave and passive infra-red (PIR). Infrared radiation exists in the electromagnetic spectrum at a wavelength that is longer than visible light. Infrared radiation cannot be seen but it can be detected [6]. Objects that generate heat also generate infrared radiation including animals and the human body. PIR sensors are temperature compensated to avoid any change in parameters with change in the environment temperature. The passive infrared motion detection depends on the difference in temperature between the object and its environment [8] (Rokonet, 2000). The detector uses adaptive technology to distinguish between a real intruder and the false detection by using a combination of heat sensitive and motion sensitive technology. The PIR is sensitive to thermal radiation interferences and microwave is sensitive to radio frequency interferences. The sensor continuously learns its surroundings and automatically adjusts itself to offer the ultimate reliability even in harshest environments [7]. The microwave channel is an active channel. The detector transmits an electromagnetic signal and compares the reflected from the all objects in the protected area. A moving object is identified using the Doppler effect of the comparing transmitted and reflected signals. The Doppler signal is analyzed and if its suits the detection criteria it will generate a microwave alarm [9].

The microwave channel is very sensitive to movement and has much higher detection capability than the PIR channel [6]. The combining these technologies dramatically raises the detector immunity which lead to a low false alarm ratio. The improvement in the false alarm ratio is achieved because both technologies have to detect simultaneously in order to generate output (voltage form) for solid state relay. Output signal from the sensor is very small and not enough to switching a solid state relay. The signal is amplified by using an op-amp amplifier in order to improve the signal then the signal is able to switching the solid state relay. In this design the inverting op-amp is selected to amplify the signal sending by sensor. Inverting amplifier provided the safety feature which grounding the high reverse current generated by load. An op-amp in the inverting configuration along with the power supply connections +Vcc and -Vcc. To analyze this circuit, Kirchhoff's Current Law (KCL) is used to determine the output node voltage V_0 and the circuit voltage gain given by the formula:

$$A_V = \frac{V_0}{V_i} = -\frac{R_f}{R_1} \tag{1}$$

It is important to distinguish between the voltage gain of the circuit and the open-loop voltage gain of the op-amp. Note that the final gain is negative, thus the name *inverting amplifier* [10]. However, a negative gain is not desired. In such a case, one could either use the output of the inverting amplifier as the input to a second inverting amplifier which would cause the total gain to be positive [11].

C. *Solid State Relay*

A solid state relay actually is not a relay at all. There is no relay present, just the electronic does the switching automatically an electrical equipments It works same way as a relay by using the low voltage to switch to a higher voltage [12] (Hamer, 2002). This solid state is positioned in between one of the 220/240V AC wires although it is common practice to leave the neutral wire and switch on the phase or hot wire. A signal that has been amplified then will send to solid state relay (SSR) in voltage form. A solid state relay will activated since a DC voltage is supply at the input of the circuit. The SSR provides optical coupling to a phototransistor or photodiode array, which in turn connects to driver circuitry that provides an interface to the switching devices at the output. With certain input voltage, the diode inside the optoisolator lights up and activates the phototransistor device is typically a transistor or triac. The relay will pass DC current to both directions, because one feet is conductive in one direction when relay is turned on and the protection diode inside other FET will always pass the current through. Due to the fact that this SSR passes DC to both directions, it can also be used for controlling AC [13] (Engdahl, 1999).

The AC voltage to a certain value which will activate the thyristor. The voltage over the triac at the moment is only a couple of volts so that practically the whole 220/240 AC voltage over the load. A suitable triac for application has been selected in order to handle the high voltage for switching the load. The triac must be able to handle the highest voltage present in the mains voltage. For 240V AC the highest voltage is around 325V, so a 400V or 600V triac model is more safety and more reliable. The triac must also handle the maximum continuous current running though the circuit [14]. The triac is protected via the 100nF capacitor and the 39 ohm resistor which connected in parallel with the triac. If the sensor has detect the present and thermal radiation by human, then the fuzzy rule make a decision, solid state circuit will activate and switching the electrical appliances (load) ON.

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III. RESULT AND DISCUSION

Fuzzy controller: The system structure identifies the fuzzy logic inference flow from the input variables to the output variables. The fuzzification in the input interfaces translates analog inputs (crisp value). The fuzzy inferences take place in rule blocks which contain the linguistic control rules [1;2]. The outputs of these rule blocks are linguistic variables. The defuzzification in the output interfaces translates them into analog variables (crisp value) .

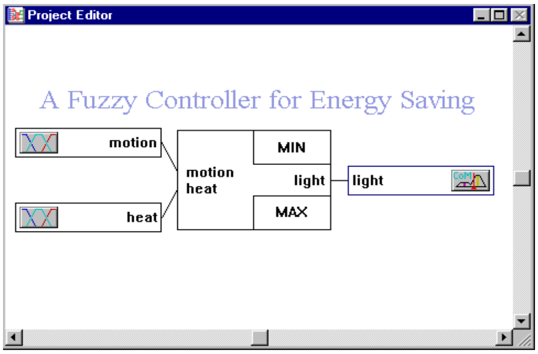

Fig. 3: Project Editor for Fuzzy Logic Controller

Linguistic variables are used to translate real values into linguistic values. The possible values of the linguistic variable are not numbers but so called ‘linguistic variables terms’ [2] (Glower and Munighan, 1997). The degree to which the crisp value belong to a set is represented by a value between some range 0 to 40 as shown in the Fig. 4. This value is called the degree of membership. Degree of membership equal to 0 means that a variable definitely does not belong to a set, while the degree of membership equal to 40 reflects absolute membership. Fig.4 shows values of heat that have two membership fucntion – high and low.

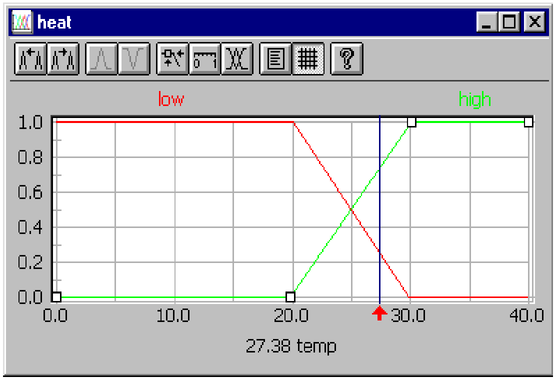

FIG. 4: The Fuzzy Input Variable ‘Heat’

Degrees of membership for all input is assigned. This value is change of presence of a user in the covered area of thr sensor. The values are: 0 for minimum detection motion and 1 is for maximum detection motion by sensor. By using debug, the degree of a parameter can simply be seen on the linguistic variable frame in Fig. 5 below.

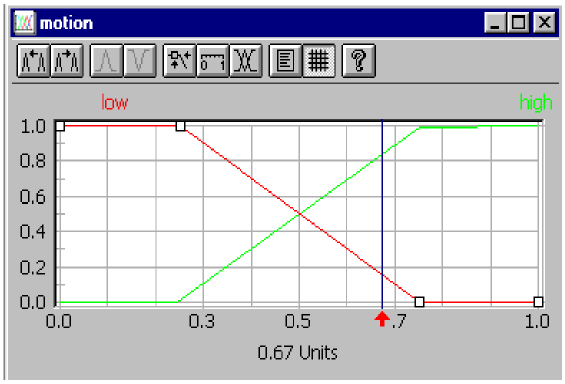

Fig. 5: The Fuzzy Iinput Variable ‘Motion’

Fig. 6 shows values of firing angles that is set 0 to 1. It just has two membership functions, on or off. This output is controller by centre of maximum (CoM) defuzzification method. The Centre of Maximum method (CoM) does this by computing a crisp output as a weighted mean of the term membership maxima, weighted by the inference results [1] (Driankov, Hellendoorn, and Reinfrank, 1993). The locations of the individual term when membership is maxima are indicated by the gray arrows and the inference result is shown by the height of the black bar in the arrow.

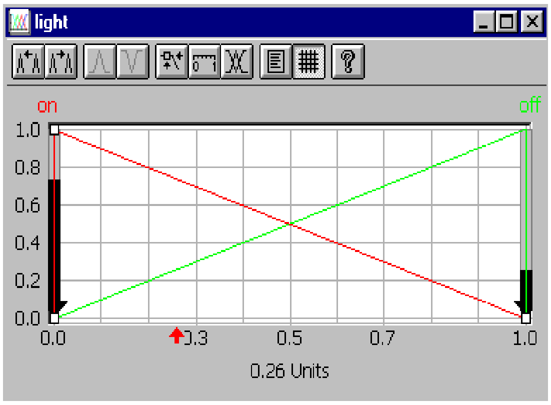

Fig. 6: The Fuzzy Output Variable 'Light'

Most fuzzy logic based system use production rules to represent the relation among the linguistic variables and to derive actions from sensor inputs. Production rules consist of a precondition (IF-part) and a consequence (THEN-part) [1]. The rule block that contain the control strategy of the fuzzy logic system is shown in Table 1. Each rule block confines all rules for the same context. A context is defined by the same input and output variables of the rules. The degree of support (DoS) is used o weigh each rule according to its importance.

TABLE 1
FUZZY CONTROLLER RULE BLOCK

Spreadsheet Rule Editor - RB1

Matrix	IF		THEN	
Utilities	motion	heat	DoS	light
1	low	low	1.00	off
2	low	high	1.00	on
3	high	low	1.00	off
4	high	high	1.00	on
5				

Output sensor: There are some results from the output of a sensor while detecting of human presence or not presence. Fig. 7 below shows the output waveform from a sensor when making a detection. The output signal from the sensor is in analog which provide a signal in voltage form. Output sensor is very small and not sufficient to transfer the signal for determination and evaluation. By using an operational amplifier and making a certain adjustment of the gain, a small output voltage from the sensor can be amplified at desired value.

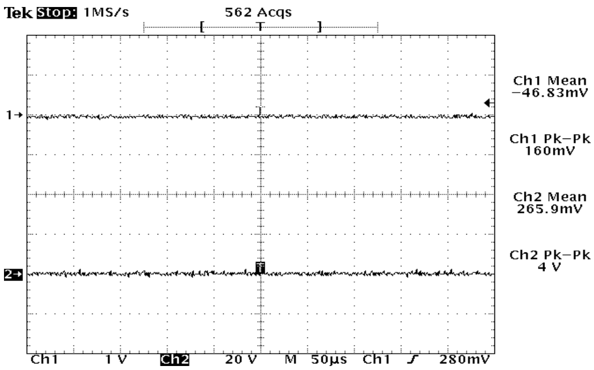

Fig.7: Waveform of the Output Sensor for No Human Presence

Fig. 7 shows there is no output waveform since there is no human presence, which means that there is no signal provided at the output of the sensor when a material with no thermal is presence. Mean value at the output of the sensor is -46.83mV. At channel 2, mean value through an operational amplifier is 265.9mV.

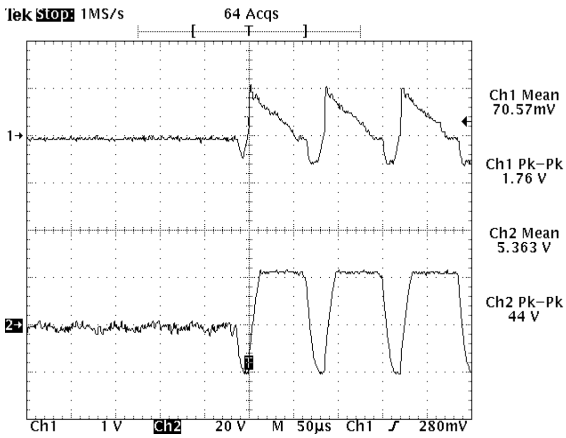

Fig. 8: Waveform of the Output Sensor Detecting a Human Presence

Fig. 8 shows a waveform based on the detection of a sensor when it's sensed a presence of human around the area that it's covered. Mean value at the output of the sensor since doing detection is 70.57mV. After amplification by using an operational amplifier, the mean value of an output increases to 5.363V.

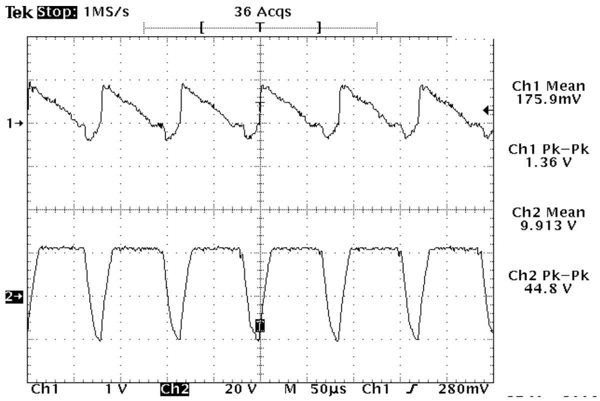

Fig. 9: Waveform of Output Sensor for Full Detection

Output value of the sensor always changes based on a degree that it's making the detections. Value obtained before amplified will affect the value after amplified by small amount of changes. There is waveform of the output sensor when there is maximum detection of human presence. Mean value for maximum detection of the sensor is 175.9mV. The value increases to 9.913V after amplification., The output waveform generates smoothly and Fig.s out absolute waveform in a frame when compared to another as shown in Fig. 9 above.

IV. CONCLUSION

The fuzzy controller was designed with partial fuzzy if-then rules to control the artificial lighting in a smart way for energy savings and energy efficiency. In this design the fuzzy controller starts with four basic fuzzy if-then rules. Any signal detected will be decided by fuzzy controller and sending the signal to an actuator for some physical action. The behavior of the system can be observed at the each level of the fuzzy control. By computing the fuzzy systems, it follows the combinination of a collection of recommended action which consist of linguistic concept, membership function, fuzzification, fuzzy rule inference and defuzzification. The system is based on a sensor and fuzzy controller then sending the signal to an actuator for implemention of some physical action to generate a desired output.

The design can be improved and developed for commercial use. It is able to reduce on electrical expenses and made the system intelligent by automatically controlled it in a building. The. solid state relay can do the handling of higher voltages for more variety of applications.

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