Faculty of Mechanical Engineering

MULTI-OBJECTIVES OPTIMIZATION OF ENERGY CONSUMPTION OF IKM BINTULU BUILDINGS TOWARDS ENERGY SAVING

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MULTI-OBJECTIVES OPTIMIZATION OF ENERGY CONSUMPTION OF IKM BINTULU BUILDINGS TOWARDS ENERGY SAVING

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DECLARATION

I declare that this report entitled "*Multi-Objectives Optimization of Energy Consumption of IKM Bintulu Buildings Towards Energy Saving*" is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature	:	
Name	:	Muhamad Naim Bin Othman
Date	:	14.11.2016

APPROVAL

I hereby declare that I have read this report and in my opinion this report is sufficient in terms of scope and quality for the award of Master of Mechanical Engineering (Energy Engineering).

Signature : .....

Name of Supervisor : Dr. Mohd Zaid Bin Akop

Date : 14-11-2016

ABSTRACT

The power consumption of air conditioning and lamps in IKM Bintulu buildings contribute a high billing cost and power consumption of the total energy. The consumption is needed to ensure the comfort of working and learning environment for staffs and students as well. Hence, this project proposed a method called "Multi-Objective Optimization of Energy Consumption" in order to optimize the power consumption in the buildings without neglecting the comfort of the staffs and students called an occupants. The method applied the Genetic Algorithm (GA) to unravel the multi-objective optimization problem that involved the power consumption and the comfort of the 200 occupants. The method is focused on the room temperature (°C) and the light illumination (Lux). The experiments are conducted by using one air conditioning and 12 units of fluorescent lamps called 12 nos with 36 Watts rated in a 40 meter square (m^2) room. The algorithm is classified as optimization and without optimization method that been used to simulate to find the weight fitness of chromosome which the input is intensified as air conditioning temperature and lighting illuminance (Lux). The methods are differs by the setting parameter of temperature of 24°C and lighting of 500 Lux for optimization method, while 18°C air conditioning temperature and 540 Lux for without optimization method. A survey and questionnaire is carried out to 25 staffs and students to observe the impact before (without optimization) and after (optimization) the experiment is conducted. The results from GA indicates that the optimization method can save up to 18.04% in daily cost (counts in RM), 18% of power consumption (kWh) and 17.98% of current. The values is considered as success rate if the optimization is applied for the whole buildings in IKM Bintulu. Meanwhile, the survey shows that 63% agreed that the room temperature is set to default of 24°C all day and 77% agreed the lighting illumination is set to 500 Lux. The survey concluded that 76% occupants are comfortable after the optimization method is implemented to the air conditioning system and lighting illuminance.

ABSTRAK

Penggunaan kuasa untuk penghawa dingin dan lampu di dalam bangunan IKM Bintulu menyumbang kepada kos bil yang tinggi dan penggunaan kuasa dari jumlah keseluruhan tenaga. Penggunaan itu diperlukan untuk memastikan keselesaan dalam persekitaran kerja dan belajar untuk staf dan pelajar. Justeru itu, projek ini mengemukakan kaedah yang dipanggil "Multi-Objective Optimization of Energy Consumption" dalam mengoptimumkan penggunaan kuasa di dalam bangunan tanpa mengabaikan keselesaan staf dan pelajar yang dipanggil penghuni. Kaedah itu menerapkan algoritma genetik (GA) untuk merungkai masalah pengoptimuman pelbagai objektif yang melibatkan penggunaan kuasa dan keselesaan 200 penghuni. Kaedah itu memfokuskan kepada suhu bilik (°C) dan pencahayaan lampu (Lux). Eksperimen dijalankan dengan menggunakan satu penghawa dingin dan 12 unit lampu kalimantang yang dipanggil 12 nos dengan kadar 36 Watt di dalam bilik berkeluasan 40 meter per segi (m^2). Algoritma itu diklasifikasikan sebagai kaedah optimum dan tanpa optimum yang digunakan untuk mensimulasi dalam mencari kesesuaian berat kromosom dimana masukannya adalah penghawa dingin dan pencahayaan lampu. Kaedah itu dibezakan dengan tetapan parameter dimana suhu ditetapkan kepada 24°C dan lampu ditetapkan kepada 500 Lux untuk kaedah optimum, manakala 18°C suhu penghawa dingin dan 540 Lux untuk kaedah tanpa optimum. Kaji selidik telah dijalankan kepada 25 orang staf dan pelajar untuk melihat impak sebelum (tanpa optimum) dan selepas (optimum) eksperimen dijalankan. Keputusan dari GA menunjukkan bahawa kaedah optimum dapat menjimatkan setinggi 18.04% dalam kos seharian (dikira dalam RM), 18% dalam penggunaan kuasa (kWh) dan 17.98% arus. Nilai itu dianggap sebagai kadar kejayaan jika kaedah optimum diterapkan ke keseluruhan bangunan di dalam IKM Bintulu. Sementara itu, kaji selidik menunjukkan bahawa 63% setuju suhu bilik ditetapkan kepada 24°C sepanjang hari dan 77% setuju pencahayaan lampu ditetapkan kepada 500 Lux. Sebagai kesimpulan dari kaji selidik itu, 76% penghuni berasa selesa selepas kaedah optimum diterapkan kepada sistem penghawa dingin dan pencahayaan lampu.

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LIST OF ABBREVIATIONS

ACO	-	Any Colony Optimization
CCHP	-	Combined Cooling, Heating and Power
MW	-	Mega Watt
FLC	-	Fuzzy Logic Controllers
GA	-	Genetic Algorithm
GCGA	-	Generalized chromosome genetic algorithm
MAPE	-	Mean Absolute Percentage Error
MILP	-	Mixed integer Linear Program
PSO	-	Particle Swarm Optimization
SBX	-	Simulated Binary Crossovers

LIST OF SYMBOLS

°C	-	Temperature in celcius
m^2	-	Meter square
V	-	Voltage
Hz	-	Hertz
A	-	Ampere
W	-	Watt
Lux	-	Illuminance of light
nos	-	Luminance of fluorescent lamp

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CHAPTER 1

INTRODUCTION

1.1 Introduction

In every year, Malaysia's consumption of energy is increase. The demand of the electrical energy in 2008 was 522 199 GWh and keep increasing by years where the transportation and industrial domain were the two largest consumers of energy. The third largest user which include 14% of energy was residential and commercial sectors. The agriculture sector was the least consumer with only 1% from the total energy in Malaysia. The average consumption of energy in Malaysia was 2 645 GWh per year. The expected electricity consumption by 2020 in Malaysia is increasingly about 30% from the present value, 124 677 GWh.

There number of the energy used also have a relationship between GDP (Gross Domestic Product) and Malaysia's electricity consumption. The increasing in GDP means the economic growth and the production will also increase. Table 1.1 shows Malaysia's electricity consumption from 1970 t0 2010. In 1980s, the sources of gas and coal being relied for electricity. In 2010, the gas and coal is estimated contribute 92% of the electricity generation.

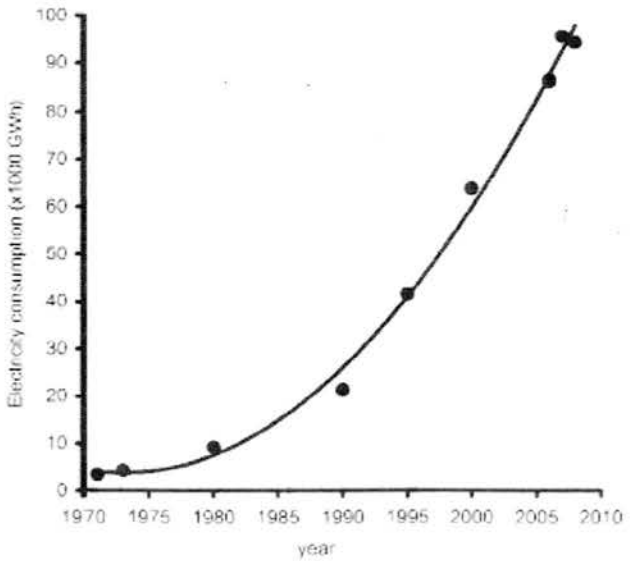

Figure 1.1: Malaysia's electricity Consumption (1970-2010)

Malaysia's government has started introduced renewable energy as fifth sources for electricity generation such as biomass and biogas from the oil palm. The other major for renewable energy source is solar radiation. Since Malaysia is located near at the equator of earth, the weathers are almost sunny at day and mild at night for throughout the year. It means, Malaysia receives a high radiation in solar with 3 kWh per square meter per day.

The cost is about RM22.50 for every 1 kWh of electricity generated per year. So, for photovoltaics contribute to even 10% of expected electricity demand by Malaysia in 2020, the total cost of photovoltaics would be around RM280 billion.

Geothermal power is another source of renewable energy in Malaysia, but it is still undeveloped. Indonesia and Philippines is already utilizing geothermal as a source of electricity. The geothermal in Indonesia and Philippines produced about 1197 MW and 1940 MW respectively. Now, one of the potential geothermal reservoir was discovered in Tawau, Sabah which has the potential to produce an electrical energy of 67 MW.

1.1.1 Illumination and thermal comfort in the building

Light is effective when it corresponds to the visual needs for worker. Good lighting is the right amount of the light at the right place. Veitch and Galsiu (2006) opined that artificial lighting is needed to provide task luminance and adequate visual environment to carry on the task when the natural light is not available. Good artificial can minimizing eye strain to prospect health, prevent from accident and also can contribute to the office's beauty.

Thermal comfort is defined as the mind condition that express comfortness and satisfaction based on environment temperature. It is difficult to fulfil since the level of comfort is varies from people, by concerning the personal factor such as the size of body, and environment factors such as working environment. All these factors will determine the level of comfort and satisfaction. The best of thermal environment is can satisfy the majority of people in the workplace. Health Safety and Environment (HSE) consider that 80% of the people in the workplace should be thermally comfort in an environment.

Thermal comfort is very important because when people work in uncomfortably environment, their performance can be deteriorates. The environment feels comfortable when people are barely aware of climatic conditions. It is only when temperature increase and decrease beyond ones comfort limits that one become aware of discomfort (Jorn Toftum,

2002). The comfort zone for the clothes person in the winter is about 20-22°C and for the summer is 20-24°C. A decrease in temperature may make people less attentive and restless and increase in temperature above the comfort level may make people sleepy and tired.

It can be conclude that Malaysia will confront with challenges to handle the highly demand and the way to apply the sustainable practices for energy. The objective towards energy saving can be achieved by increase the energy efficiency and management, and implementation of sustainable energy source.

1.2 Objectives

There are several objective of the project to be achieved, which are:

i. To obtain the power consumption and comfort building towards energy saving
ii. To use the algorithm (GA) as an optimization method
iii. To compare the performance of optimization process with current practice.

1.3 Scope of Works

The limitation of the research work is defined in this scope of work, to ensure the contents of project are confines the scope. This project began with the actual room in Azadegan room with the area 40 meter square (m^2) as illustrated in Figure 1.2.

The next stage is the literature review on comfort building and optimization of power consumption. After that, the mathematical model will verified with the respect to the illumination and temperature as an input and power consumption and an output comfort. The next step is design the optimization algorithm namely generis algorithm (GA) to develop the experimental data. Then by using the MATLAB and Simulink, the GA will simulate the level of comfort based on the algorithm technique that mimicking the real thinking of human brain, without neglecting the real objective to conserve the electrical energy.

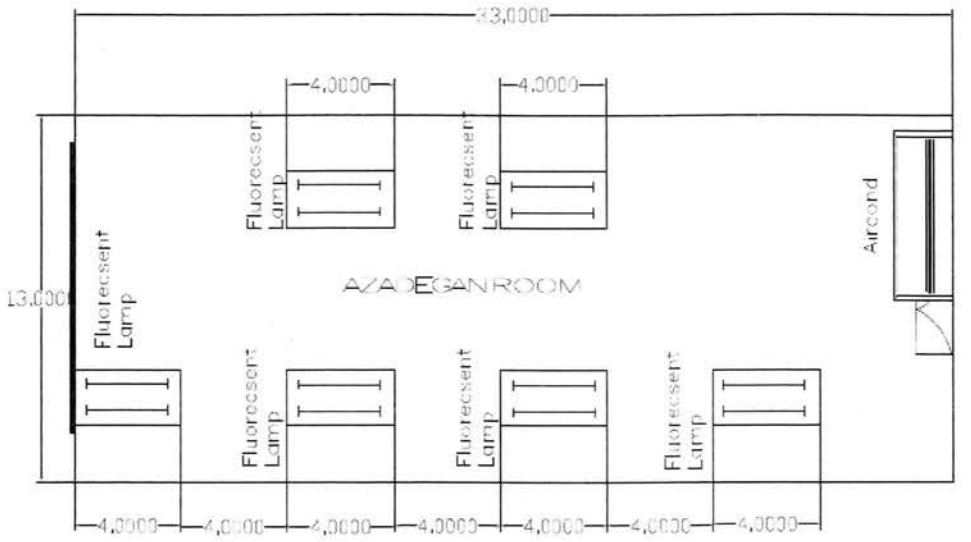

Figure 1.2: Actual Building in IKM Bintulu

1.4 Thesis Outline

The thesis present the implementation of the multi objectives optimization of power consumption and comfort in IKM Bintulu building toward energy saving.

Chapter 2 discuss the previous works done by researchers in power consumption and comfort. In this chapter, explained the related research on modelling of power consumption and comfort that related and facilitate to this project.

Chapter 3 depicts the method and steps taken that been applied in this project. It covers the model, explanation in detail on how to determine the level of comfort, the variables and parameters selection and the generic algorithm optimization method.

Chapter 4 explain the GA simulation result of the model and the multi-objectives optimization method. This chapter included multi-objectives optimization method results compared the non-optimization method result.

Chapter 5 present the conclusions of the project and suggestion for the further development in this topic area. This chapter also conclude the outcome of the project with some suggestions are highlighted.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Chapter 2 is briefed in several sub-chapter as follows:

i. Overview from previous works regarding the multi-objectives optimization of power consumption and comfort.

ii. Overview of the previous researches about using genetic algorithm (GA) and the other optimization method for minimize the power consumption and comfort.

2.2 Overview from Previous Research

Save energy in building and reduce cost of electricity will be achieved by operated Combined cooling, heating and power (CCHP) under the optimal scheme (Zhaoyi, 2011). Mixed integer linear program (MILP) is been developed and analyze in this project in order to achieve the objective, which are to conserve and optimize the electrical consumption and the monthly billing cost. The analysis proved how the performance of CCHP, which is a low-cost method, can varies under different strategies of operation.

An energy management technique based on genetic algorithms is presented by (F.Fiamingo et al., 2003). This technique is able to evolve and adapt its behaviour according to the variation of the parameters of the controlled environment, ensuring a high flexibility and efficiency in energy management and a consequent energy waste reduction.

S.Tarverdian et al. (2006) discussed in detail regarding genetic algorithm (GA) with variable parameters to forecast electricity demand in agricultural, low energy consuming and energy intensive sectors using stochastic procedures. Three kind of model in this research are linear logarithmic, exponential and quadric are used to find minimum error in the selected sectors. In this study, the application of GA produce the best coefficient with the minimum errors. Finally, an analysis and comparison is been made on the three models from GA using variance analysis technique. It is found that at $\alpha = 0.05$ the five treatments

are not equal and therefore the Duncan test is applied to see which treatment pair has led to the rejection of the null hypothesis. Furthermore it is shown that genetic algorithm estimation is closer to actual data with less MAPE (Mean Absolute Percentage Error) error than that of estimated by regression. The data from 1979 to 2003 is used to forecast electricity consumption in the aforementioned sectors as the case study.

A. Gonzalez et al. (1999) described about that more than 50% of energy is used for indoor activities while 40% of total energy in Europe is used in buildings. A controller called Fuzzy Logic Controllers (FLC) is implemented to various sectors in real world problems, based on the application conducted in the sector. The development of smart tuning method is been developed to overcome the complexity of the FLC and will enable a rational operation which improved the FLC with a simpler and efficient technique.

The problem arise when several restrictions are very complex due to time constraint, which is a long time taken, of computational time of the model and the multi-objective fitness function that widen the solution of search space. There are two stages in tuning methodology that been proposed, which are the rough global tuning (using GA technique) and the refined local tuning (using Simulated Annealing) to solve the first restriction. Multi-objective method enable to working with fitness functions with competitive objectives to solve the second restriction. The features of these tuning with different capability and multi-objective technique is the best solution to overcome the problem and solve the restrictions due to time constraint. This research is been done by the framework of Genesys European Project.

Syahputra R. (2012) presented multi objectives on how to minimize active power loss and maximum voltage magnitude to improve the effectiveness of radial distribution network with distributed generation. Multi-objectives function are considered for load balancing, the deviation of voltage, minimize the real power loss, in relation to radial network structure which stated that the loads need to be energized. To improve the efficiency of the work, the fuzzy-based multi-objectives optimization in the reconfiguration of distribution network. 70 nodes distribution network are applied by implement fuzzy multi-objective for distribution reconfiguration. The original efficiency of the network is 95.142%. The simulation results proved that the efficiency of the network is improved to 96.942% by using a fuzzy multi objective method.

Energy efficiency improvements, progress of liberalization and structural changes in industry should be monitored to control the energy supply (Unler, 2008). To achieve the objective to be an industrial nation and improve living standard, medium and long term of energy demand should be analyzed. The management in energy demand should dealing the sources and demands to a sustained and optimum manner. In this research work, a model Partical Swarm Optimization (PSO) are introduced to forecast and calculate the energy demand in Turkey more efficiency. Although there have another indicator such as population, import and export, gross domestic product (GDP), are been used as the indicators of energy demand. A comparison is made to any colony optimization (ACO) energy demand estimation model to show the accuracy of the algorithm.

Wendy Wood et al. (2012) depicted that the sustainable energy saving are very important due to rapid growth in energy demand. To build a building with multi-agent system for real applications give several challenges to researcher, regarding the scalability, optimizing multiple objectives, model uncertainty and complexity to implement the system. This work proposed a new approach to conserve energy usage effectively in a building. The work contributes a significant effect that requiring a large scale of multi-objective optimization and complexity to optimize the energy consumption but at the same time the occupants' comfortless are fulfilled.

There are three major contributions which are by developed a model called HRMM to solve the real-world application with a robust solution, but yet considering the complexity of the model in order to reduce the computational loads. Second, the results from experiment shows that the HRMM converge to near-optimal solutions and third, by providing the best solution to dealing with the insights from occupants into computational model and algorithms. The model developed is been verified in simulation and validation tested to energy savings and comfort levels of occupants.

Dionyssia et al. (2010) discussed regarding the priority in a worldwide application to improve energy efficiency. By considering several objectives, for instance, the energy consumption, billing costs, environmental performance must measures by employed to save energy and achieved an optimal solution. The researcher faced the challenge to solve the multi-objective optimization problem, even though the method is widely used, it still require an addition support like criteria decision analysis technique and simulation that exploit possibly many but in any case limited alternative options.

Multi-objective technique is been used in order to overcome the restriction by allowing the potential infinite number of measurements, evaluation based on criteria which consider the annual billing cost, the finance, the investment and the energy consumption in a building. Based on the criteria, an algorithm is been developed to set up the output decision based on the criteria and restriction allowed in the setting. To prove the theory, a case study is discussed with appropriate simulation results on functionality of the preference setting developed in the algorithm.

Norfishah et al. (2010) explained that the lighting itself contributes the highest amount of electrical consumption in a building about 20% to 50% total electrical usage in the building. Energy and cost will be save if lighting are using effectiveness and efficient. This research analyze the management of energy in the building and present the energy efficiency of the lighting system. Firstly, it proposed a design efficient lighting energy which will help people to identify the ideal number of luminaries needed in a room without reducing the lighting quality. MATLAB software will be used to develop this research.

The second part is deal with the study to optimize the cost of the wastage of lighting in commercial, residential and industrial areas. Lamp Replacement system had been proposed to improve the current system. The major findings in this works are the design of the lighting energy-efficiency is achieved without sacrificed the actual comfort and lighting quality. The replacement of older lamps with new luminaries' specification can greatly improve the efficiency.

The main objective of research study is to maximise the light illumination of daylight for indoor purpose and to control the functions of the roller blind as a regulating device to ensure the desired inside luminance with smooth roller blind moving (Zupancic B. et al., 2005). The illumination effect on lighting the room is analyzed in term of solar radiation. This research is to build environment controlled by dynamic luminance. Fuzzy logic test chamber with an opening on the south side to control automatically luminance. Fuzzy controller also been developed to overcome the external disturbance in correspond the position of the roller blind with the solar radiation.

To control the environmental parameters at the building zone level, an optimized fuzzy controller is presented by G.S. Stavrakakisb et al. (2002) via a smart card unit, the occupants' preferences are monitored. The GA optimization technique is applied on this

project to maximise the ability and function of the fuzzy controller to achieve the objective which is to satisfy the comfortless of occupants.

Andrew Hunter et al. (2001) discussed that the Empirical modelling in high dimensional are led by a feature selection stage. Any irrelevant features can degrade modelling performance and increase the complexity of the problem. Multi-objective genetic algorithms are proposed as the analysis method to evolve a diverse population of alternative features with least complexity. The method is particularly success in neuro fuzzy modelling and conjunction with a method for performing fast fitness evaluation. This paper contribute a specific type of multi objective genetic algorithm, based on the concept of dominance, for feature selection and the combination of fast fitness evaluation of neuro fuzzy models with a genetic algorithm.

Plamen Angelov (1999) discussed the framework of fuzzy mathematical programming can optimize the building thermal systems. Under given constraints, the technique is able to calculate accurately and solved the problem with the true purpose to satisfy the comfort of occupants and to conserve energy consumption. An assumption is been made in fuzzy optimization control in order to solve the problem analytically. The research stated that the comfort is improved by 38% with only 0.6% increase in electrical billing.

Sevil Sariyildiz et al. (2008) explained positioning of houses in a residential neighbourhood, Multi objective- optimization are described. There two objectives, which are garden performance and visual privacy performance requirements for building placement and favourable configuration constrained. Satisfactory operation of the algorithm is presented and Pareto-front formation in described from the analysis.

French Agency for Energy and Environment (ADEME) founded the OPTISOL framework, which is a methodology for life cycle optimization during sketch or refurbishment has been developed for professional building actors: architects, building owners, designers, HVAC engineers. First, a French typology of tertiary buildings has been created: partitioned and open space offices, hospitals, schools and nursing homes. Once done, a proposal list of systems related to each building was developed.

To minimise the number of simulations and to establish a 15 parameters function providing energy consumptions for each building with each system, in each climate,

simulation experimental designs were used. The methodology developed was implemented in a software tool to facilitate its use. Two options are proposed to users: to perform the calculation of energy consumption, CO2 emission and investment for chosen solutions or to perform different optimization calculations resulting in technical proposals. The system is implemented to integrate with a smart card unit, actuators sensors, a programmable logic controller (PLC), interfaces, a central PC, local operating network (LON) modules and devices to monitors the performance of the system.

Nadia et al. (2008) accomplished the research with several methods to determine the energy performance in a building with appropriate optimum preference with a complex desired output. In Mediterranean region, the air-conditioning is important as heating elements which produced more complex problem to solve due to the challenges climate, architecture design of the buildings and the strong effect of the summer and winter. To solve the problem, GA technique is proposed to optimize the energy usage of the buildings, with simplified tool for building thermal evaluation method is applied. The GA technique also been used to optimize the energy performance in term of reducing the used of special and expensive device, in other word, reduce the use of hardware by improve the design of the algorithm software.

The optimization of wireless sensor network layouts is explained by Olivier L. De Weck and Damien B. Jourdan (2004). A high performance communication method is connected to the sensors which served as a medium from a ground to the satellite or high-altitude aircraft in data transmission. The sensing performance were assumed to have two important characteristics which are fixed sensing range and fixed communication. The sensor placement of Multi-Objective Genetic Algorithm has considered the lifetime network and total sensor coverage. Moreover, there are two different types of layout that are used to sense at different range using MOGA. When the sensors are wisely packed together, the other sensor organized in a hub-and-spoke manner. This can be shown by the discriminating factor which can be obtained by the ratio sensing of communication range.

Hidehiro T et al. (2010) have carried out a study based on the development of energy saving system by implementing an adjustable lamp, Particle Swarm Optimization (PSO) and Wireless Sensor Network (WSN). This study is focused on reducing the amount of energy in office, thus provides an energy saving consumption. The module was set to the power of lamp after the PSO process. The system consists of some important components