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Energy management strategy with smart building control system to reduction electrical load using ANN

Bareq Musaab Jalal, Rashid Hamid Al-Rubayi
Department of Electrical Engineering, University of Technology–Iraq, Baghdad, Iraq

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ABSTRACT

Buildings have long been large energy consumers, and inadequate control of heating, ventilation, and air conditioning kinds of variable refrigeration flow (HVAC-VRF) and lighting systems. To reduce energy consumption by using a smart building control system (SBCS) in a building was created using occupant control, daylight sensors, weather condition variations, load consumed, and changes in solar power. The model was tested using MATLAB/Simulink, and it was then utilized to investigate the impact of an integrated system on energy usage based on two scenarios. The first scenario was tested in a simulation of building occupant behavior, meteorological variables, daylight sensors, temperature, and load control. This resulted in energy savings for the HVAC system (23% on summer days and 16% on winter days), and lighting system energy savings (22% on summer days and 15% on winter days). In the second scenario, the building was tested to integrate PV system power with load consumption by using the artificial neural network (ANN) algorithm to manage building load consumption by PV, grid, and diesel generator. As a result, the energy savings were 56% on a summer day and 65% on a winter day of the combined energy utilized by the HVAC and lights.

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Corresponding Author:

Bareq Musaab Jalal
Department of Electrical Engineering, University of Technology
Al Sinaa Street, Baghdad, Iraq
Email: eee.20.45@grad.uotechnology.edu.iq

1. INTRODUCTION

The biggest challenge that will be faced in the near future is increased electricity demand. Energy consumption is increasing in residential, educational, and commercial structures. Building energy consumption accounts for 30-45% of global energy consumption, with the great majority consumed by air conditioning, security, water, lighting, and other building features [1]. The system's generation and transmission capacities are approaching their limits; it is possible that the electrical generation will not be enough to cover the entire demand [2]. Technologies that conserve energy and reduce capacity are required [3]. All energy-consuming gadgets are grouped together on the demand side. Lighting and heating, ventilation, and air conditioning (HVAC) systems consume 70% of the energy in commercial office buildings [4]. The growing interest in building energy usage has accelerated the need to monitor and save energy as efficiently as feasible [5], [6]. Investigate the many approaches utilized during the energy audit in [7], [8]. Interior lighting energy management is crucial for the development of smart buildings, according to [9], and lighting that dims electric lights based on daylight levels improves energy conservation. One of the most common ways for implementing such daylight control pulse width modulation (PWM) dimming is to measure the mix of daylight and electric light and determine the dimming level of the electric light. Nagy *et al*. [10] presented the occupant controlled lighting control (OCC) technique, in which set-points are automatically created through occupant involvement, and showed the potential for a 13.4% reduction in normalized energy use. The illumination hours are organized by [11], which are regulated by a control system and switched off on a predetermined timeline. Cheng *et al*. [12] proposed to reduce lighting energy usage by establishing a smart lighting system that includes sensor technologies and a distributed wireless network. A wireless sensor network (WSN) that uses the ZigBee protocol controls the brightness of each light. Jindal *et al*. [13] addressed the issue of energy management in university buildings by minimizing the quantity of HVAC process without compromising comfort. A deterministic simulation, which involves making predictions based on predefined fixed timelines or criteria, is the most frequent way for modeling tenant behavior within structures [14]. In contrast to deterministic models, agent-based (AB) and stochastic models have shown to be the most powerful and appropriate tools for modeling complex systems. This co-simulation architecture's major goal is to mimic occupant behavior in buildings and implement an intelligent building energy management system (IBEMS). In [15], [16] considers a novel recombination probability component and a real mutation factor for analysis, and proposes a new scheduling strategy based on an adaptive differential evolution method. Pallante *et al*. [17] described a new technique for cutting building energy costs that relied on a combination of optimization and simulation produced in the MATLAB/Simulink environment. According to the data, there is a potential cost savings of 10% to 28% on average. The results of an energy consumption analysis for a commercial building with an integrated photovoltaic (BIPV) facade system are presented in [18]. Researchers developed improved control and automation for buildings and their equipment in order to achieve low energy usage in sector buildings while ignoring the load consumed and the PV input to the controllers from solar systems [19], [20].

In this paper, the use of photovoltaics (PV) to power HVAC and lighting, along with appropriate control techniques, was examined to maximize energy savings inside a building, especially in public facilities where there have been claims of excessive electricity usage. The smart building control system (SBCS) was simulated using occupant behaviours, daylight sensors, climate condition variations, load control, and PV power variations. Therefore, this paper proposed an intelligent algorithm artificial neural network (ANN) for load management strategy using PV system, grid, and diesel generators. Improved energy saving in buildings, on the other hand, can be considered one of the most precise and efficient approaches for addressing a variety of issues. It involves the design and electricity clearing of effective markets, costs, power quality, service requirements, power system reliability, and stability. However, the aims of this paper are listed as follows: i) design a SBCS algorithm model based on temperature control, occupancy detectors, daylight sensor, and load control. Capable of saving energy and monitoring, ii) design PV system with energy storage system to use power for HVAC, and lighting systems by integration with the load consumption, iii) management energy strategy by ANN uses PV, grid, and diesel generators to supply energy consumption, iv) create a comfortable, energy-efficient atmosphere and no human intervention selection.

- Related work

To improve energy efficiency, some research on device control in smart buildings has been done. The scheduling-based control approach automates the process of keeping electrical devices running by entering schedules input into the system, and energy efficiency is achieved by remote control as well as the production timetables for both wind and solar energy are taken into account [21], [22]. A new smart strategy is described that can account for the impact of next-door neighbours as well as the exterior temperature and can reduce energy consumed by using machine to machine (M2M) communications and fuzzy logic, at various set points of the HVAC system, annual energy consumption was lowered by an average of 16.5% and 12.5%, respectively [23], [24]. Furthermore, in [25] the study is a house that uses neural network predictive control (NNPC) to suggest a revolutionary strategy for the management of energy in a zero-energy building. Hakimi and Hasankhani [26] mixed-integer linear programming (MILP) is being used to transmit electricity between smart buildings could be a way to create renewable energy resources in residential areas and optimize energy usage in buildings to reduce the amount of electricity purchased from the national grid. Energy management in smart buildings, including responsive and non-responsive components and renewable PV resources, is modelled [27].

2. PROPOSED AND PROBLEMS FORMULATION

The use of mathematical models of variable refrigeration flow (HVAC-VRF) and lighting systems. One outside unit and numerous indoor units make up the HVAC-VRF model. Many split VRF units are refrigerant systems with electronic expansion valves and variable speed compressors for each indoor unit [28]. When the VRF's coefficient of performance (COP) is extremely high, the seasonal energy efficiency of these systems is high [29]. The fan uses energy when the compressors are switched off, and when the compressors and fan are both turned on, the entire system consumes energy. The fan's electric energy consumption can be calculated (1) [30].

$$P = \frac{Q\,\Delta P_t}{6350\,\eta_f} \tag{1}$$

Where P is fan power (HP) horse power; Q is air circulation rate (ft^3/min) (cubic foot per minute); $\triangle P_t$ is fan total pressure rise (in w.g) (inch water per gauge); η_f is fan efficiency, decimal.

$$Q_h = \dot{m}Cp\ (Tout - Tin) \tag{2}$$

$$m^{\cdot} = Q \times \rho_{air} \tag{3}$$

Where Q_h is heat energy transfer (kJ/h) (kilojoule per hour); $m^{\cdot}$ is mass flow rate (kg/h); Cp is the heat capacity of air (kJ/kg.K) (kilojoule per kilogram kelvin); Tout and Tin, are the outdoor and indoor temperatures respectively (°C), Q is air circulation rate (m^3/h); ρ_{air} is density of air (kg/m^3). The measurement of the temperature outside during the year was taken every hour by the general authority for meteorology and seismic monitoring (GAMSM). In winter season performance of coefficient heating (COP_{heat}) is the ratio of production energy output (Q_{out}) to heat energy consumed (E_h) [31].

$$Q_{out = Q_{h+P}} \tag{4}$$

$$COP_{heat} = \frac{Q_{out}}{E_h} \tag{5}$$

$$SHR = \frac{\text{sensable load}}{\text{total load}} \tag{6}$$

$$\text{Senable load} = Q \times \rho_{air} \times Cp \times \triangle t \tag{7}$$

Which SHR is sensible heat ratio, sensible load (kW), total load (kW), total capacity of heat in winter, total capacity of cool in summer, ($\triangle$ t) (difference between ambient temperature and the temperature room). The amount of energy used by HVAC-VRF during winter is calculated using (2) and (5).

$$E_h = \frac{\dot{m}Cp\ (Tout - Tin) + P}{COP_{heat} \times SHR_h} \tag{8}$$

In summer season

$$COP_{cold} = \frac{Q_{out}}{E_c} \tag{9}$$

$$E_c = \frac{\dot{m}Cp\ (Tout - Tin) + P}{COP_{cold} \times SHR_c} \tag{10}$$

The power consumption of lighting type light emitting diode (LED) was calculated with the number of lights used in the building.

$$Pl = \frac{V^2 \times P.F}{\text{Resistive load}} \times \text{No. of lights} \tag{11}$$

Which Pl power consumed by LED, P. F. (power factor).

2.1. HVAC-VRF, lightings energy consumption based on occupancy detector, temperature, daylight sensor, and load control strategy

Based on the preceding equations, HVAC-VRF energy usage varies as the temperature of the office changes, an occupancy management plan to reduce energy usage by occupancy sensors is put in offices, meeting rooms, and conference rooms to inform if the space is used or empty. As a result, let (Wt) (refer to occupied) $\in \{0,1\}$ be defined as the detector for occupancy and ventilation and air conditioning state variables as:

$$Wt = \begin{cases} 1 & \text{if Room occuiped} \\ 0 & \text{if Room not occuiped} \end{cases} \tag{12}$$

Cooling is required in most offices and meeting spaces. There will be three levels of room temperature. ($\mathrm{Troom} \in \{\mathrm{Tcold, Tmed, Thot}\}$) from (9) summertime energy use ($\mathrm{E_c}$) and the limit of energy usage threshold (Th). The control planning is described as:

$$\mathrm{Troom} = \begin{cases} \mathrm{Tcold\ if\ Wt = 1, Ec < Th} \\ \mathrm{Tmed\ if\ Wt = 1, Ec\ otherwise} \\ \mathrm{Thot\ if\ Wt = 0, Ec < Th} \end{cases} \quad (13)$$

The proposed MATLAB/Simulink control see Figure 1 was used to create and simulate a diagram that was controlled by occupancy, temperature, weather, and load control. The input parameters were made with blocks, and the controller block was made to change numerous inputs in order to decrease the total of energy used. In the summer season VRF must be (ON) in (Tcold) at (23 ℃) set if the place is occupied (14). When the room is unoccupied the VRF should be (Thot) at (26 ℃) (15), If the amount of electricity used by the VRF system exceeds a certain level value threshold (Th), the HVAC must be ON in the (Tmedium) at (25 ℃) mode (16), with feedback output power to permit the controller to take another resolution,

$$\mathrm{E_c} = \frac{\mathrm{\dot{m}Cp\ (Tout - Tcold) + P}}{\mathrm{COP_{cold} \times SHR_c}} \quad (14)$$

$$\mathrm{E_c} = \frac{\mathrm{\dot{m}Cp\ (Tout - Tmed) + P}}{\mathrm{COP_{cold} \times SHR_c}} \quad (15)$$

$$\mathrm{E_c} = \frac{\dot{m}Cp\ (Tout - Tmed) + P}{COP_{cold} \times SHR_c} \quad (16)$$

in winter season,

$$\mathrm{Tro}om = \begin{cases} \mathrm{Thot\ if\ Wt = 1, Eh < Th} \\ \mathrm{Tmed\ if\ Wt = 1, Eh\ otherw} \\ \mathrm{Tcold\ if\ Wt = 0, Eh < Th} \end{cases} \quad (17)$$

The occupancy detector, which controls HVAC-VRF, should turn (ON) in the (Thot) at (23 ℃) set if the place is filled; otherwise, HVAC should turn (ON) in (Tcold) at (20℃) set. Depending on feedback energy usage that choice saves energy. Thus, during the winter, when an office is filled and power consumption is greater than limit of energy usage (TH), HVAC should turn (ON) in (Tmeduim) at (22 ℃).

The power of lighting type LED was calculated with the number of lights used in the building. As shown in Figure 1. Employer movements inside and outside of the office were examined to build an illuminance energy control plan in the office. Solar radiation will be relied on through the daylight sensor, which means if the office has lighting up to (500 lux), the controller will turn (OFF) the office lighting and rely on solar radiation. Let (Pt) be the amount of energy spent through the lights at time (t) to indicate whether the place is occupied or not, and let ($\mathrm{Wt\ (occupancy)} \in \{0,1\}$) be the state changeable for the motion detector in 12, and (Pl) power usage by LED can be determined as follows:

$$\mathrm{Pl} = \begin{cases} \mathrm{Pt} & \mathrm{if\ Wt = 1} \\ 0 & \mathrm{if\ Wt = 0} \end{cases} \quad (18)$$

$$\mathrm{Pl = Pt \times Wt} \quad (19)$$

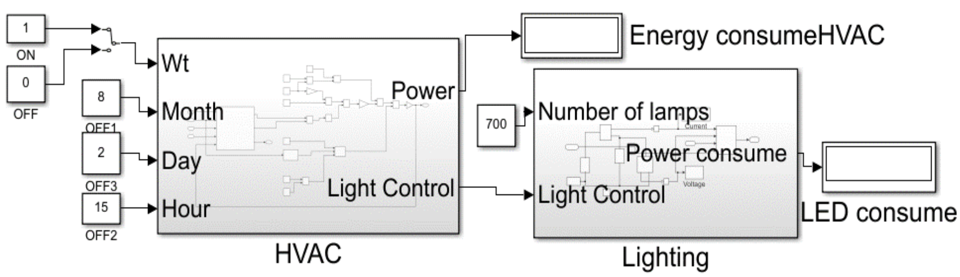


Figure 1. Energy consumed of (HVAC-VRF) and lighting system

3. ENERGY SUPPLIES MODEL

A smart building employs a localized energy management strategy. The building is equipped with a programmable HVAC-VRF and lighting system to ensure air quality and visual and thermal comfort and therefore contains baseload controllable loads, local renewable energy generation systems, and possible energy storage systems (ESS), grid, and diesel generator (DiG) capacity 400 kW supply load in case PV generation, grid not available. In this part, we focus on the PV system and the ESS. They've been modelled and simulated in order to save even more electricity around the public building, and the technology of ANN control is aimed to manage regulated loads (HVAC-VRF, lighting) by prioritizing the PV system to feed the building's load.

3.1. Photovoltaic system

A solar photovoltaic model was connected to the grid. A mathematical formula for the solar panel was built in MATLAB/Simulink PV designed here was 100 kW, according to Table 1. PV parameters under standard conditions 1000 W/m^2 irradiance and 25 °C temperature. The total number of PV panels (n_{panels}) can be calculated.

$$n_{panels} = \frac{\text{Total power need to generated (KW)}_{AC}}{\text{Nominal power for pv panel (W)}_{DC}} \tag{20}$$

Total voltage for PV array:

$$V_{PV} = n_s \times V_{MPPT} \tag{21}$$

total current for PV array:

$$I_{PV} = n_p \times I_{MPPT} \tag{22}$$

total power for PV array:

$$P_{PV} = V_{PV} \times I_{PV} \tag{23}$$

Table 1. PV (trina solar TSM-310PA14) specifications

Parameters	Max. power	Vmpp, Impp	Open circuit voltage	Short circuit current	No. of cells in series	No. of cells in parallel
Ratings	310 W	36.8 V and 8.42 A	45.3 V	9.4 A	23	14

3.2. Energy storage system modeling

ESS are devices installed within a power system that can store and release energy [32]. Using and releasing energy are key components of this implementation. ESS with a maximum capacity (S_{max}) is installed in a smart building during the equation.

$$S_{max} = \frac{P_{tc}}{DOD \times V_b} \tag{24}$$

Where S_{max} (capacity power covered from a battery, ampere-hour, Ah), P_{tc} (power total consumed, kW), depth of discharge (DOD) which value 80%, V_b (battery voltage, volt), to determine the number of batteries required for coverage (100 kW), and 52 batteries were used in accordance with the specifications in Table 2.

Table 2. Battery (LFP smart 12,8/200) specifications

Parameters	Nominal voltage	Nominal capacity @ 25 °C	80% DoD	No. Battery connect series	No. Battery connect parallel
Ratings	12.8 V	200 Ah	2500 Cycle	4	13

3.3. Energy management strategy

The PV system's primary goal is to decrease energy usage. Around public buildings and ANN algorithm design to manage controlled loads (HVAC-VRF, lights) in smart buildings by prioritizing the PV system to serve the building's electrical loads [33]. In addition, the proposed smart control in the above uses

sensors based on an occupancy detector, daylight sensor, temperature, and load control strategy. The benefits of smart control include comfort, energy-saving, safety, and energy management used in smart buildings, they also contribute to lowering energy costs and maintaining a clean environment. This energy management method can be organized in five different operating conditions, illustrate in Figure 2(a) (see in appendix).
Mode 1: when electrical loads less than powered supplied by PV, in this mode grid will be offline.
Mode 2: when loads exceed PV supply, the grid, in conjunction with PV, will feed the loads.
Mode 3: when electrical loads rise and the PV source power output is reduced, in this mode grid with batteries, if chargeable more 90% will feed loads.
Mode 4: when electrical loads rises and the PV source provides less power, and batteries charge less than 30%, in this mode grid will feed loads
Mode 5: when loads rise and the PV sourc output is lower, and grid OFF, this mode (DiG) supplied loads.

3.3.1. Proposed model ANN strategy management

One of our key goals is to integrate ANN management systems into electrical networks. This section, will build a management model based on the integration of ANN to manage the system while keeping the five modes of operation in mind. To obtain flexibility with this management, we will guarantee the continuity of energy supply to the consumer, reduce energy consumption by PV systems are given first consideration to supply load in smart buildings, protect the battery, and increase its lifespan. In this paper, the proposed controller work has four inputs, power load consumption from smart building after using SBCS, which is dependent on occupancy, daylight sensors, temperature, and load control to determine loads of (HVAC, lighting), PV system with (EES), grid, and (DiG). When the PV system is available to supply load or when PV generation is less than the load, the model prioritizes PV and grid supply loads. The output enables the switch networks that transport the output to the end-user. Feed forward neral network based to levenbarge-marquardt (LM) method to train the ANN, which begins by finding the output (y) of each neuron in the network and then calculating the mean square error (MSE). The weights are then changed using the gradient (g) as indicated.

$$\mathrm{MSE} = \frac{1}{2}\sum_{k}(\mathrm{d} - \mathrm{y}) \tag{25}$$

$$\mathrm{G} = \frac{\partial \mathrm{MSE}}{\partial \mathrm{W}} \tag{26}$$

Which k number of output neurons, d output target vector, W weight network to find the best MSE and the smallest number of neurons in the hidden layer, the data set were built in MATLAB.

3.3.2. Training NN with (LM)

Several elements that demonstrate the resilience and reliability of the created EMS, which prioritizes PV system power supply. The number of iterations and time required to reach the least square error value is shown in Figure 2(b) (see in appendix) (the convergence of the outputs to the desired outputs). The learning curve in Figure 3 shows that the value of the error goal is equal to 3.16×10^{-12} after 88 epochs, indicating that the learning method is convergent. This value is high enough to ensure a high classification rate. This indicates that if the network parameters (weight and bias) are appropriately ANN will be able to govern the system [34].

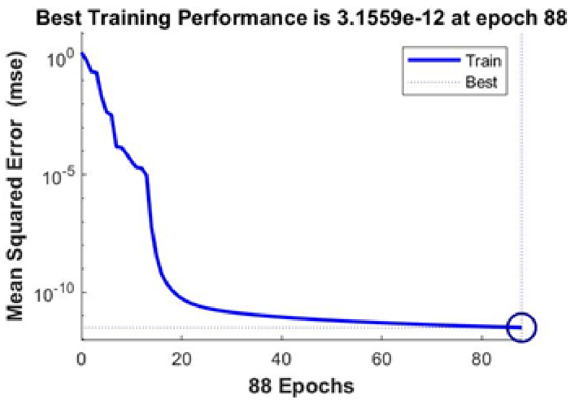


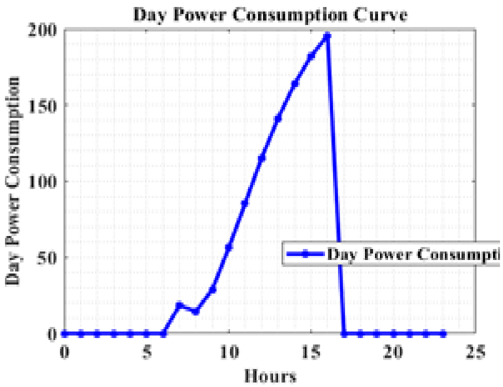
Figure 3. MSE of ANN training in MATLAB

3.4. Case study

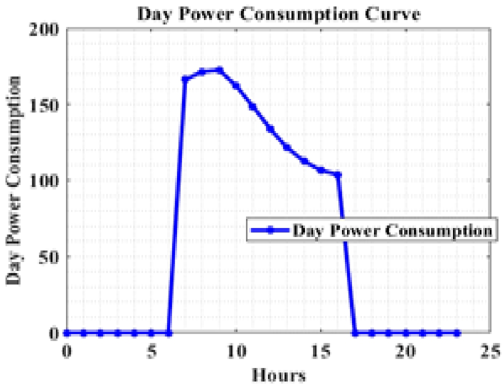
Study's building is the national investment commission (INC) located Iraq (Baghdad). It made up of six floors. Total floor area is 1,335 m^2 each floor, HVAC-VRF consists of 10 units with a capacity of 291,700 btu/h type LG. The lighting used is a 15-watt spotlight number 1122 and LED fitting with (60 watts) numbers 740.

4. SIMULATION RESULTS AND DISCUSSION

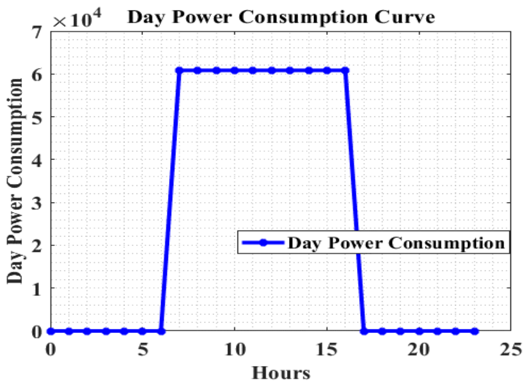
Results of HVAC, lighting systems energy consumption without control (base case), each hour's cooling and heating degree day ambient temperatures in Baghdad are taken from GAMSM. Figure 4(a) represents the energy consumption used to cool the building during the summer on day 15/July and Figure 4(b) represents the heating of the building during the winter on day 15/January. Figure 4(c) represents the power consumption of lights in a building according to the number of lights utilized. We discovered that the average temperature for a certain office and meeting area is 23 ℃, while ten units of energy consumption are (1,002 kWh) during the summer and (1,399 kWh) in winter, lighting system energy consumed (608.24 kWh).



(a)



(b)



(c)

Figure 4. Power usage without control (a) HVAC summer day, (b) HVAC winter day, and (c) lights system

4.1. HVAC-VRF energy consumption based on SBCS model

The SBCS model combines the benefits of occupancy sensors and temperature control with load control in HVAC. The energy consumed during one day in Figure 5 represents simulated results of VRF energy consumption in summer (Ec) and winter (Eh) days with temperature and occupancy control. Summer working hours are 864.71 kWh and in winter they are 1225.13 kWh. Figure 6 represents simulated results after occupancy, temperature, and load control. Because of equations (Tmed summer and winter), the energy consumed by the office's rooms automatically lowers when the energy threshold is reached in winter, as the inside temperature, which is the benchmark temperature of 23 ℃ in winter during the occupied period increases by one degree 24 ℃ and drops to 23 ℃ in summer. The (E_c) in summer season day after load control in addition occupancy and temperature control are 759.41 kWh, (E_h) in winter season 1175.2 kWh.

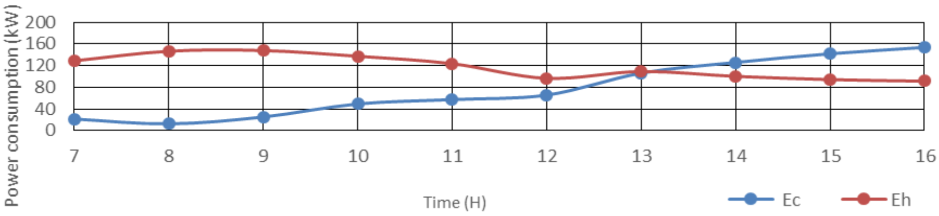


Figure 5. Energy consumed after occupancy, temperature control during one day in summer and winter

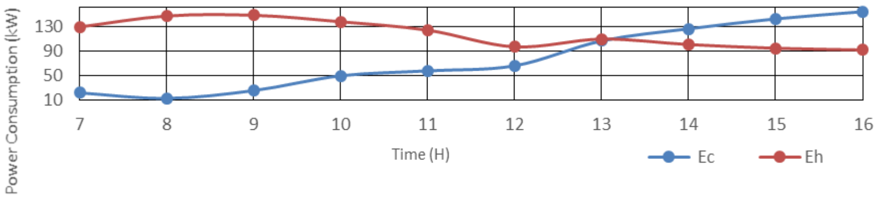
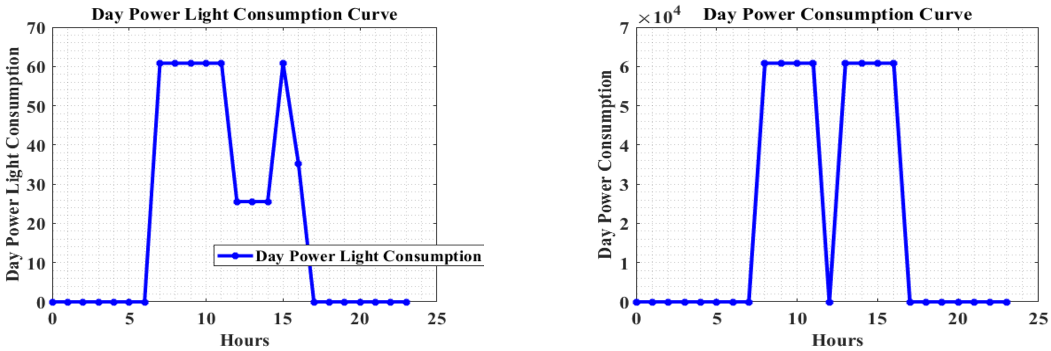


Figure 6. Energy consumed after occupancy, temperature, and load control during summer, winter day

4.2. Lighting systems energy consumption based on SBCS model

In lighting, the SBCS is dependent on occupancy and daylight sensors to maintain electrical power in the building. Actual work has been done for the building, and lights are (ON) when offices are occupied and (OFF) when offices are vacant. Daylight sensors work to compare solar irradiation inside the office room with the validation of 500 LUX, the lights are turned off in the office. Figures 7(a) and (b) represents simulation results of occupancy, daylights sensors on summer day and winter day respectively according to working hours of building, energy consumed (Pt) in summer days 476.86 kWh, in winter day energy consumed 516.96 kWh. Figure 8 combined HVAC energy consumption in summer day (Ec) and energy consumption in winter day (Eh) with lighting system energy consumed (Pt), resulted power consumption in summer day (1478.86 kWh) and (1916.62 kWh) in winter day.



(a) (b)

Figure 7. Lightings energy consumed for (a) on summer day and (b) on winter day

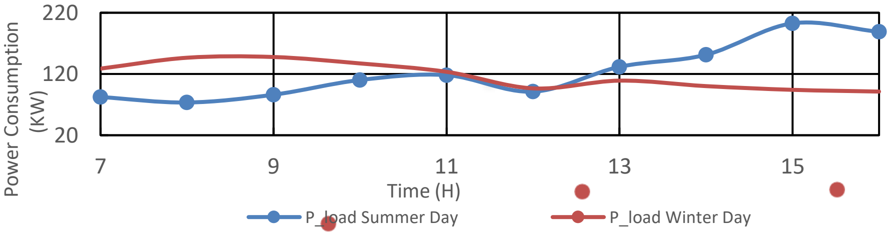


Figure 8. HVAC, lightings power consumption during summer, winter day

4.3. Photovoltaic simulation results

Table 3 was simulated one-day data collection in 15/July summer and simulation PV system in winter day in 15/January. The amount of energy produced by the PV system is affected by irradiance and temperature. The simulation of a PV system with a capacity 100 kW represented in MATLAB/Simulink.

Table 3. Photovoltaic power generation

Summer day time	PV generation kW	Winter day time	PV generation kW
8-9 am	58.7	8-10 am	23.8
9-12 pm	70.4	10-12 pm	45.7
12-14 pm	96.89	12-14 pm	35.6
14–16 pm	68.88	14-16 pm	22.3

4.4. Results of energy management system PV, grid, DiG by using ANN

In this part, attempt to test the efficiency of the NN management solution, under different test conditions. To better analyse the performance and accuracy of our control scheme, PV values are chosen from photovoltaic simulated to integration with grid that is PV system generated (P_{pv}) and grid available Figure 9 will show that the source (P_{pv}) and grid, supply loads (P_{load}) of building after SBCS, which (P_{load}) represents combined loads of HVAC-VRF Systems and lighting, in case grid not available, the (P_{pv}) with DiG supply loads according to Table 3 which represents PV generation in day summer and day winter, the load supply by PV and grid Figure 10 represents power loads (P_{load}) in summer, winter day supply by integration PV and grid. As shown in Figure 11(a) PV system and the grid both supplied power to the offices in summer day but the PV system is given priority to supply load by ANN to become energy consumption (453.92 kWh) and Figure 11(b) showed PV system and grid supplied power to the offices during winter day and energy consumption become (856.3 kWh) during working hours.

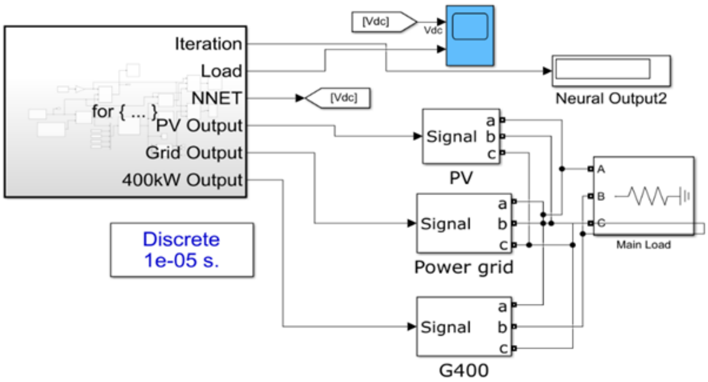


Figure 9. Energy management system to supply loads

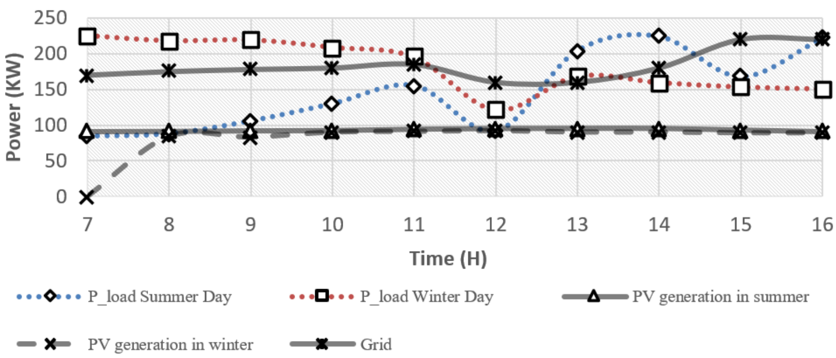
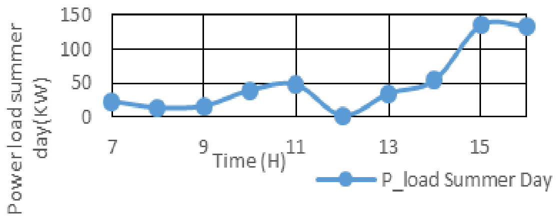
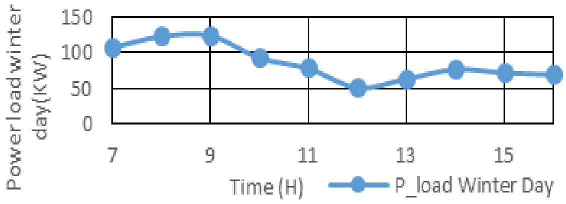


Figure 10. PV generation and grid feed total power load consumed in building (during summer, winter day)



(a)



(b)

Figure 11. Power load consumed after PV feeding for (a) summer day and (b) winter day

4.5. Model validation

The proposed model superiority in terms of energy savings is demonstrated by the use of occupancy, daylight, temperature, and load sensors. Then integration of the PV system with SBCS by ANN. are depicted in (refer to Figure 11). In addition, Table 4 compares energy savings of proposed and small models, including strategy, to the suggested models in this paper in [12], [13]. Cheng *et al.* [12] proposed creation of a distributed (WSN) in an office room. The problem is formulated (MILP), and a heuristic-based approach is proposed to minimize HVAC usage while maintaining user comfort [13].

Table 4. Comparison energy saving various models

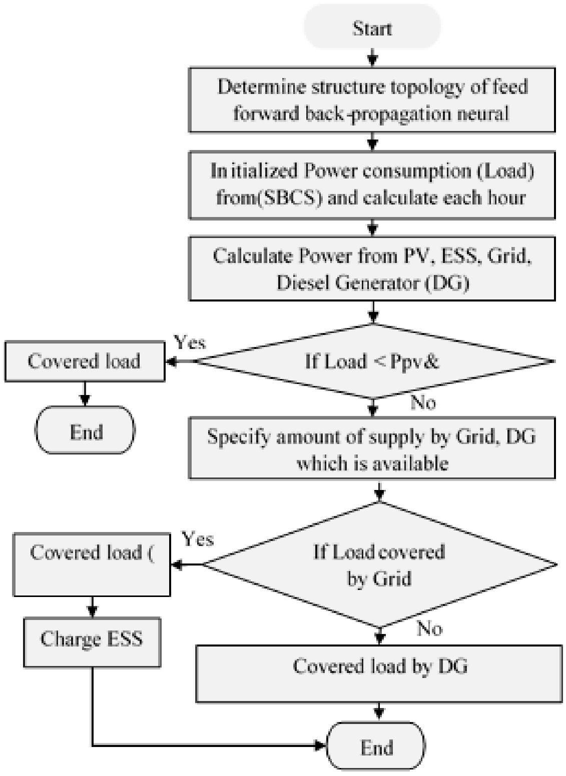
Model	Proposed SBCS without load control	Proposed SBCS with load	Proposed SBCS with PV system	Distributed WSN use ZigBee [12]	Used MILP and Heuristic algorithm to minimize load [13]
Energy save %	13% HVAC, 20% light	18% HVAC, 20% light	60.5% HVAC & Lightings	36% light	19.75% HVAC

Due to Table 4, three possible comparisons of results: i) when comparing energy consumed without control refer to Figure 4 vs SBCS without load control Figure 5 according to occupancy sensor, temperature control, SBCS with load control Figure 6 dependent above and in addition to load control in (summer, winter day) we will note SBCS reduction energy usage about (13% in summer, winter day) and with load control improved values energy efficiency of HVAC about (10%, 4% in summer, winter day) compared to (base case), ii) when comparing energy consumed for lightings system without control Figure 4(c) vs SBCS Figure 7 dependent on occupancy, daylights sensor, noteed SBCS minimize energy consumed (22% during summer day) and (15% during winter day), (iii) combined energy consumed (P_{load}) for HVAC, lightings in summer, winter day Figure 8 after SBCS and made integration PV system, grid, by ANN which given priority to PV supply load consumed, Figure 11 improved to minimize (P_{load}) (56%, 65% in summer, winter day).

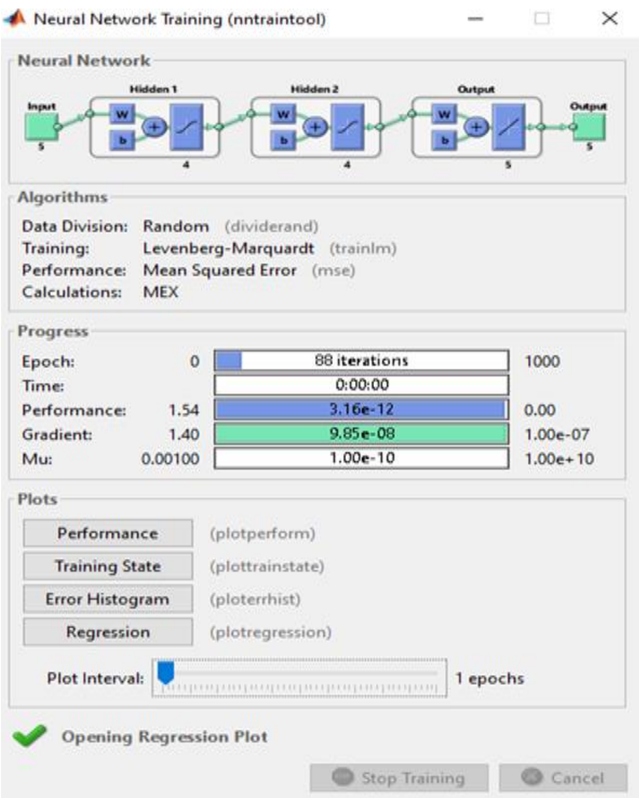
5. CONCLUSION

This paper proposed two models to increase energy saving for HVAC-VRF, lightings system inside building, first model the proposed SBCS consist of occupancy control, daylights sensor, temperature control, weather condition, and load control. The results showed that the energy saving for one day during summer 15/July and winter 15/January automated. (NIC) building study was greater compared with not controlled (23% for HVAC in summer day, 16% for HVAC in winter), lightings system energy saved (22% in summer, 15% in winter), secondly model integration strategy of PV with SBCS which conducted further minimize energy consumption in building (56%, 65% in summer, winter respectively), ANN algorithm used to manage building loads consumption by PV, grid, DiG, deciding when PV would have supported by grid to supply energy.

APPENDIX



(a)



(b)

Figure 2. Represented (a) flowchart energy management and (b) ANN training by LM in MATLAB

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BIOGRAPHIES OF AUTHORS

Bareq Musaab Jalal was born in Baghdad, Iraq in 1989. He received the B.Sc. degree from Electrical Engineering from University of Al Mostansiryah, Iraq in 2011. in 2020. He is currently working toward the M. Sc degree in Electrical Engineering at University of Technology, Baghdad, Iraq. His research interests are the area energy managemnt, power quality. He can be contacted at email: eee.20.45@grad.uotechnology.edu.iq.

Professor Dr. Rashid Hamid Al-Rubayi was born in Baghdad, Iraq in 1956. He received the B.Sc. degree from Basrah University, Iraq in 1979, M.Sc. and Ph.D degrees both from Polytechnic institute, USSR in 1986 and 1990 respectively, all in electrical power engineering. Dr. Rashid is currently Professor in the Department of Electrical Engineering, University of Technology, Baghdad, Iraq. His main research interests are power system analysis and operation, power system stability, power system protection, power quality, reactive power control and FACTs devices. He can be contacted at email: 30062@uotechnology.edu.iq.