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ARTICLE

Heat Transfer in Horizontal Copper Tube Heated by Electric Heating Process

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ABSTRACT

Heat transfer from electrical and electronics component is essential for better performance of that electrical system, The maximum heat transfer from that system results long period durability. In most of the system base provided for equipments are very small and placed in a very complicated position. so heat transfer by forced convection is not easy for that purpose. The heat transfer by natural convection is the familiar technique used in electronics cooling; there is huge group of apparatus that lends itself to natural convection .This category consist of stand-alone correspondence such as modems and small computers having an array of printed circuit boards (PCB) accumulate within an area. Natural convection heat transfer in heated horizontal duct drive away heat from the interior surface is offered. The duct is open-ended and round in cross section. The test section is heated by provision of heating coils, where constant wall heat flux mentioned. Heat transfer experiment is carried out for channel of 50 mm. internal diameter and 4 mm thickness with length 600 mm. Ratios of length to diameter of the channel are taken as L/D = 12. Wall heat fluxes maintained at q// = 300 W/m^2 to 3150 W/m^2. A methodical investigational record for the local steady state natural convection heat transfer activities is obtained. The wall heating condition on local steady-state heat transfer phenomena are studied. The present experimental data is compared with the existing theoretical and experimental results for the cases of vertical smooth tubes.

1. Introduction

Heat transfer by Natural convection is a consistent, commercial way for the rapid rising electrical and electronic manufacturing industries, in electrical and electronics systems number of heat producing elements are provided on a little base. need It is required to cool, as that components heated first, if proper cooling method will not provided then that total base will damage, It is found that in some places that base are provided in very complicated position, so in these cases natural convection heat transfer is best suitable, as forced convection by provision of fans are not possible.

In Natural convection heat transfer by density difference, density changes with temperature as volume changes by temperature. when air heated by some external

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source heating its density decreases and moves up, that empty space filled by cooled air from surroundings.

Therefore information on heat transfer by natural convection surge from end to end limited spaces has been found helpful particularly in the thermal fluid structure. For its significance, the heat transfer by natural convection case has usual growing notice in the literature in current years. The intention of this exertion is to learn the concept and basic by theoretically and experimental the natural convection flow through pipes at various heat flux levels. Heat transfer experiment is conceded for channel 50 mm. internal diameter and 4 mm thick having length 600 mm. Relative amount of length to diameter of the pipe is taken as L/D = 12. Constant Wall heat fluxes maintained at q// = 300 W/m2. Wall heating condition on local steady-state heat transfer phenomena are studied. The basic aim of this experiment to find temperature profile and to indicate the variation of temperature along length of the pipe.

Number of work on natural convection heat transfer was there, it found that there was maximum intension on natural convection heat transfer through heated vertical tubes. But our work on natural convection heat transfer through heated horizontal tube.

Alawi et.al [1] studied heat transfer through horizontal annulus found that outcome for the normal Nusselt numbers are match up to with prior works and illustrate good conformity.Mallik and Sastri [2] deliberate experimentally the natural convection heat flow over an range of spread out distinct upright plates and originate that the use of discrete vertical plates in comparison with continuous plates gives rise to enhancement of natural convection heat flow. Nayak et al. [3-4] calculated datas by experimental examination on natural convection heat flow in heated vertical tube and found that enhancement of heat transfer, Nayak et.al. [5] studied on natural convection heat transfer in heated vertical tubes with and without internal rings and compared the data found from the work with existing and theoretical. Sparrow and Prakash [6] have examined the free convection through a stagger assortment of discrete vertical plates. They match up to the concert of a staggered array of discrete vertical plates with that of a parallel flat channel, allowing for the wall at consistent temperature. Their outcome indicate that better spacing, shorter plate and smaller heights of the control provide improvement of heat transfer. Tsuji [7] from his work found that there is maximum heat transfer of the turbulent natural convection boundary layer can be significantly accomplish in a ample area of the turbulent natural convection boundary layer by utilize several column rip heat flow promoters. It may be predictable that the heat flow enhancement in excess of approximately 40% can be accomplished by put in that type promoter.

Abdel-Aziz and Sedahmed [8] studied heat flow at horizontal spiral tube by natural convection and found that natural convection give a great agreement to the rate of transfer than forced convection. Blaszczuk and Jagodzik [9] studied Heat transfer feature in an exterior heat exchanger with horizontal pipe bunch and found that the standard HTC raise with a diminish of the Sauter mean element span and with the enlarge of the fluidizing figure as an effect of high-quality addition dynamics in suspension stage (i.e. emulsion wall contact time, bubble fraction in the bed). base on the heat transfer information, experiential relationship are planned for forecast a heat transfer coefficient from fluidized bed to flat tube bundle. Aldoori, and Ahmed [10] studied The result of altering tube diameters on improvement heat flow by forced convection from end to end a horizontal tube and found that the ideals of the local Nu (LNu) are forever reduce and achieve its lowest value at the tube way out section of the imposed HF. For all pipes, the outcome illustrate that an enlarge in the pipe diameter outcome rising in Nuav. Nemati et.al [11] studied Natural convection heat flow from horizontal annular finned pipe based on customized Rayleigh Number variety of Ra offer a absolute image of natural convection over round annular finned pipes, specially at comparatively small Ra. Finally, the conclusion behaviors of the planned relationship were contrast with those of obtainable correspondence. Gogonin studied Heat transfer at boiling of liquid film irrigating a flat bundle of irregular tubes and found that Heat flow at steaming on these tubes is clearly more strong than that on a smooth tube. Zhang et.al [12] studied property of inactive air on concentration heat flow over a horizontal pipe and found that inactive air was a main factor that affect the heat and mass transfer consistency of vapor. Unlike in clean vapor condensation, the temperature dissimilarity among the top and bottom division of the condensation pipe augmented when the mole part of stagnant air was fewer than 0.17, whereas it reduced when the mole fraction of inactive air was better than 0.47. The increase in the mole fraction of inactive air abridged the temperature dissimilarity along the perimeter of the condensation tube wall. Nayak.et.al. [13] validate his experimental work with theoretical.

2. Experimental Procedure

The generally investigational system shows in figure1, it contains the whole equipment and major apparatus. The investigational arrangement has a test section, an electrical circuit consists of measuring system like thermocouple, milli voltmeter. The investigation system is a cylindrical open ended pipe. The cross-sectional outlook

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of the horizontal tube is given in Figure 2. In this work a hollow cylindrical tube is made of copper having 50 mm in diameter and 4 mm thickness. nine Copper-Constantan thermocouples are used to observe temperatures on the internal surface of the horizontal tube and also at exit, at entrance locations of the pipe shown in the figure 2. Holes are drilled on horizontal surface of the pipe, where thermocouples are inserted. After inserting thermocouple holes are filled by providing good thermal conductivity material, seven numbers of thermocouples are provided on horizontal surface and two thermocouples at entrance and exit to measure the inlet and exit air temperature.

After providing thermocouples on surface of horizontal pipe, an electric heating coil is provided on surface of the tube, the heating coil is heated from external electric circuits by provision of transformer and other electric equipments, after that the copper tube is insulated by number of insulating layers, a layer of glass wool (10mm thick) is provided on the outer surface of the tube. A layer of phenolic foam of 15mm thickness is provided over the glass wool and then the Then a layer of aerogels 20 mm thickness is wound over the phenolic foam. a very thin aluminum foil may be used for reducing the radiation heat transfer.

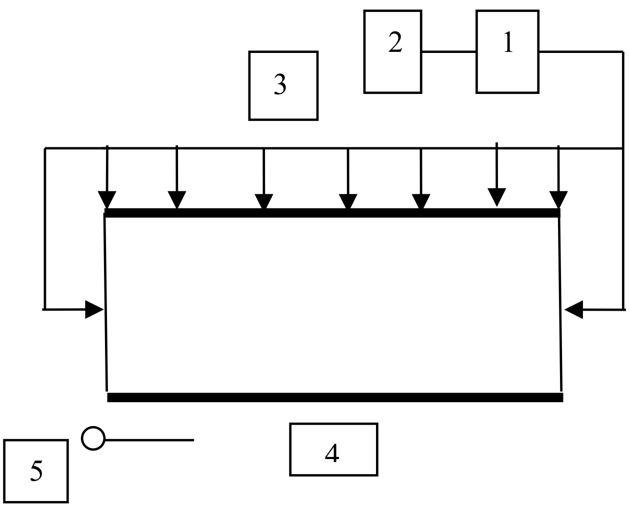

Figure 1. Experimental Set-up. 1. Selector switch, 2. Milli voltmeter, 3. System of thermocouples, 4. Test section, 5. Thermometer

The figure 2 shows cross sectional view of the test section, where points marks on surface of horizontal copper tube shows the position of thermocouples, copper tube heated by electric heating coils, heated air flow from one side of horizontal tube to another side, heat from copper tube is not allowed to outside by provision of insulating layers, temperature on surface of tube at various locations throughout its length are measured by thermocouples,

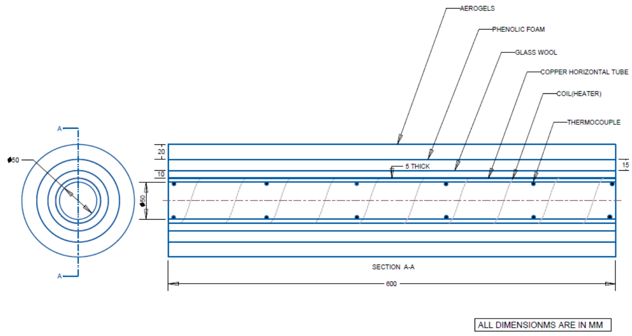

Figure 2. Cross-sectional view of the Test section

3. Results

Test was carried out for smooth tubes of different L/D proportion as 12, and for different heat fluxes are exposed in design and shown in figure 3, where length of horizontal tube was taken as in abscissa (X-axis) and Temperature measured from thermocouple are shown in Y-axis, heat fluxes are taken from range of 409 W/m2 to 3150 W/m2.

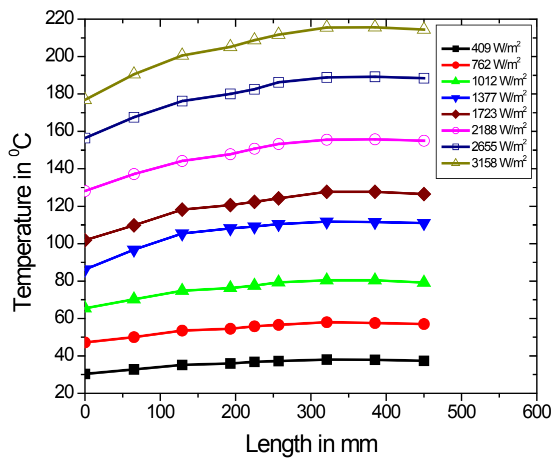

Figure 3. Confined wall temperatures for L/D ratio 12, L=600mm

Characteristic axial distinction of confined temperatures on wall of the horizontal copper tube for L/D ratio as 12 and for various heat fluxes range of 409 W/m^2 to 3150 W/m^2. are given in plotted figure 3 for smooth pipe of diameter 50 mm, length 600mm . It found from experimental plot that increase of temperature by the side of the length of the cylinder. But a little shrink at the end, which is due to loss of heat from the end of the pipe.

4. Conclusions

(1) Confined temperature of wall amplify by the side of the length of the pipe but diminish a little at the end,

which is due to heat loss from the last part of the pipe.

(2) Channel outlet temperature is least at the middle of the test section and enlarge towards the length of the test section for cases measured in this investigational analysis.

(3) Typical heat loss rate from the inside face of the heated horizontal pipe extend with provision of inner rings.

(4) Typical heat loss rate augment with mounting the ring with greater thickness up to a convinced limits, away from which it reduce.

References

[1] Alawi, O.A., Sidik, N.A.C., Dawood, H.K. Natural convection heat transfer in horizontal concentric annulus between outer cylinder and inner flat tube using nanofluid. International Communications in Heat and Mass Transfer, 2014, 57: 65-71.

[2] S.K. Malik, Sastri, V. M. K. Experimental investigation of natural convection heat transfer over an array of staggered discrete vertical plates, Journal of Energy Heat and Mass transfer, 1996, 18: 127-133.

[3] Nayak R C, Roul M K, Sarangi S K. Experimental investigation of natural convection heat transfer in heated vertical tubes. Int J Appl Eng Res., 2017, 12: 2538-2550

[4] Nayak, R.C., Roul, M.K., Sarangi, S.K. Experimental investigation of natural convection heat transfer in heated vertical tubes with discrete rings. Experimental Techniques, 2017, 41(6): 585-603.

[5] Nayak, R.C., Roul, M.K., Sarangi, S.K. Natural convection heat transfer in heated vertical tubes with internal rings. Archives of Thermodynamics, 2018, 39(4): 85-111.

[6] E. M.Sparrow, Prakash. Enhancement of natural convection heat transfer by a staggered array of discrete vertical plates,ASME Journal of Heat Transfer, 1980, 102: 215-220.

[7] Tsuji T, Kajitani T, Nishino T. Heat transfer enhancement in a turbulent natural convection boundary layer along a vertical flat plate International Journal of Heat and Fluid Flow, 2007, 28: 1472-83.

[8] M.H.Abdel-Aziz, G.H.Sedahmed. Natural convection mass and heat transfer at a horizontal spiral tube heat exchanger, Chemical Engineering Research and Design, 2019, 145: 122-127.

[9] Blaszczuk, A., Jagodzik, S. Heat transfer characteristic in an external heat exchanger with horizontal tube bundle. International Journal of Heat and Mass Transfer, 2020, 149(119253).

[10] Aldoori, W.H., Ahmed, A.H. The effect of varying tube diameters on enhancement heat transfer by forced convection through a horizontal tube. Journal of Advanced Research in Fluid Mechanics and Thermal Sciences, 2020, 66(2):158-167.

[11] Nemati, H., Moradaghay, M., Shekoohi, S.A., Moghimi, M.A., Meyer, J.P. Natural convection heat transfer from horizontal annular finned tubes based on modified Rayleigh Number. International Communications in Heat and Mass Transfer, 2020, 110(104370),

[12] Zhang, J., Fu, J., Du, J., Yuan, W., Zhou, D., Wang, Z. Effects of stagnant air on condensation heat transfer over a horizontal tube. Experimental Thermal and Fluid Science, 2019, 108: 95-103.

[13] Ramesh Chandra Nayak, Manmatha K. Roul, Ipsita jena, Ipsita Dash, Ashish Ku. Patra, Validation of Heat Transfer between Theoretical and Experimental from the Internal Surface of Vertical Tubes with Internal Rings Heated by Electrical Heating Coils, Electrical Science & Engineering, 2019, 01(01).

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ARTICLE

Safe Power Outlet

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ABSTRACT

The main goal of the safe power outlet project is to make power outlets smart and integrate it to all old and new electrical wiring of homes and offices to eliminate the costs. Using the designed socket, home and office electrical appliances can be smarten and controlled remotely through wireless technology. The device designed in this project, is a smart power outlet that supports Wi-Fi connection and the user can connect directly to it and control it by the specific mobile application. There is no need for any other interfaces such as a modem or router, and the user can connect directly to the device. This is the innovative part of the project making it different from the conventional power outlets on the market. All home and office appliances running on AC power can be connected to a safe outlet directly and without an interface; they can be controlled via wireless network by mobiles. This device smartens all old and conventional outlets without making any changes in wiring. It also enables the control via Wi-Fi on the outlets.

1. Introduction

Lighting system is an integral part of all buildings with different uses [1]. Power outlets provide energy for all electrical devices in buildings and workshops [2]. In today's world of construction, lighting system is a special subject and is defined differently. In the past, the purpose of the lighting system was only to provide optimal lighting in each part of the building in accordance with the intended use of that part. But today, in addition to its previous definition, the lighting system has various uses such as combining different types of interior lighting with various interior designs and spaces, volumetric and decorative lighting, changing and dynamic lighting style of an environment for use in different times and situations, multifunctional uses of the environment, etc.

With these new applications, the lighting system is now part of engineering field and has led to special professions. Certainly, with the increasing advances in the lighting industry, new management and control styles have been formed along with it to make the operation of the lighting system easier than before, and it has formed the so-called "intelligent lighting system" topic, which can be used to

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manage energy consumption as well as remote control of the building [3].

In this section, we express some of the disadvantages of the conventional lighting systems and also discuss the advantages of intelligent lighting to highlight the choice of intelligent lighting in the current market of building construction over its conventional counterpart from all aspects.

2. Disadvantages of Conventional Lighting Systems

(1) Impossibility to change the type of control: if the control of a conventional lighting system is through one of the switches of single pole, double pole, conversion and cross, it will be the same all the way up and you can only control the lighting line using the switches.

(2) Frequent blackouts during changes and repairs: in the case of a dead bulb or changes and repairs in the path of a lighting system, you have to cut off the power of the fuse controlling that headline. Obviously, that fuse is not only controlling the headline, but also the electric curtain, video doorbell, and socket in the path of the fuse may be off which will make repairs impossible during the dark hours.

(3) High energy consumption without saving: in the conventional lighting design, as your control over the lighting sections is only through the conventional switches mounted on the walls, you cannot manage to reduce energy consumption and the only way to reduce energy consumption is to manually turn off the switch for that headlight.

(4) Frequent bulb burn-outs: with the passage of time and aging of the building, wearing of conventional switches on the path of headlights cause a delay in the time of voltage changing or oscillations from 0 to 220 volts, which reduces the shelf life and eventually burns the bulbs. This is more evident on energy saving bulbs.

(5) Numerous conventional wall switches: undoubtedly, this is the most important defect. In new buildings, and especially the large ones, a lot of lighting sources are used. If the lighting system is implemented in a conventional way, the number of conventional switches on the interior walls of the building will be high. This issue is not considered until the building is ready to settle in. The main disadvantages include: difficult infrastructure wiring, difficult installation of switches next to each other, high volume of wires behind the switches, high insecurity and possibility of high downtime, high cost of buying switches, lots of switches on the walls, inappropriate and inconsistent appearance with modern decoration of the building, and most importantly difficult selection of the switch which controls the desired headline.

(6) Impossibility of using new lighting systems: in the conventional design, it is not possible to use a variety of new lighting technologies, and many new lighting products cannot be added to our conventional system and used properly.

3. Advantages of Intelligent Lighting System

(1) Flexibility: in the intelligent lighting system, you can easily enter the headlight of a new lighting into your smart home system and take control of it through all communication and intelligent control ports.

(2) Implementing a variety of energy saving plans: you can easily reduce your power consumption for lighting by creating various intelligent scenarios and have integrated control over each of the lighting headers or full control over all of them.

(3) Changing the light intensity or dimming the light: in the smart system, you can dim your lights and change the light intensity or in the form of various scenarios; in this way, your space can have different levels of brightness. You can also easily convert a headline that was previously an ON/OFF headline to DIMMER mode without any infrastructure changes and take advantage of it.

(4) Ability to change scenarios: your lighting system is intelligent and you can have different lighting scenarios in different spaces of your building, such as entry, living room, study, sleep, TV mode, leaving home, travel, security, etc. Most importantly, you can integrate your lighting system with sound systems, heating and cooling, electric curtains, etc. in specialized and efficient scenarios.

(5) Using smart wall switches with a high number of poles (high output): using a variety of smart wall switches to suit your taste and also your space, instead of the large number of conventional switches on the wall, a smart switch is installed in any space of your building. Therefore, in addition to controlling each of the lighting headlines, you can also run various scenarios, and also control other equipment such as smart heating and cooling, smart audio system, smart electric curtain, etc.

(6) Brightness control through intelligent remote and close communication ports: with lighting intelligence, wireless sensor networks (WSN), upgrade of communication protocols, distributed intelligence for smart objects, wireless radio frequency systems, and several other technologies and communicative solutions together have made possible the promising technology of Internet of Things (Manu Elappila, Suchismita Chinara, Dayal Ramakrush-

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na Parhi). Wireless energy transmission has received so much attention today [4] and you can control the brightness of your space through different interesting communication ports. Intelligent communication ports are smart wall switches, remote control, control via mobile phones and tablets, control outside the home via the Internet and SMS, as well as control and management with a variety of sensors in different logic layers.

(7) Stylish shape and ease of intelligent management and control: wall switches are the first communication port in the smart system, which are certainly more beautiful than conventional single-pole, double-pole, and converter switches. Also, since they come with LCD displays, lights, remote control, built-in thermostat, and scenarios, it is easier to use them in controlling the equipment.

(8) Convenience in repairs and changes: when changing the bulbs of a headline or repairing it, only that headlight is off during the change and repair, and all the fixtures in its vicinity can have their own electricity and normal use, which is a feature to bring comfort, and also provide security and safety.

(9) Reducing the final costs of the building's electrical system: the implementation of the building lighting infrastructure based on the smart design is different from its conventional design. Some costs of consuming equipment such as wires and pipes may be added, but the implementation of this plan is much easier for the electricity infrastructure operator (project electrician), and wiring is standardized, costs of conventional switches and various thermostats are saved. The installation of the equipment is much easier and faster. Moreover, the final costs of the electrical system of the building are reduced.

In addition to the mentioned advantages, working with intelligent systems at all levels and equipment such as intelligent lighting, intelligent heating and cooling system, intelligent electric curtains, intelligent sound system, etc. brings high pleasure and satisfaction for its users. Everyone will realize this important feature once they experience working with a smart home.

The main goal of the safe outlet project is to combine conventional and smart types, because in the conventional type it is not possible to use new lighting systems and in the smart type it is not possible to adapt them to conventional wiring or products of different companies, which leads to the monopoly of intelligent systems and unconventional pricing. For this reason, the innovative design of safe outlet can remove all the limitations of conventional and intelligent systems and is flexible with all conventional and intelligent systems. In this regard, we have used the ESP8266 module in this outlet:

4. Ways to use ESP8266 module

(1) Sending AT commands from computer to module by USB to TTL converter. This method is mostly used to test and set up the module.

(2) Connecting the module to the microcontroller and using ESP8266 as a peripheral device: in this method, AT commands are sent to the module to set up and work with the module through the serial port of the microcontroller.

(3) Direct programming of the processor on the ESP8266 module and using the GPIO pins of the module to communicate with other devices: in this method, there is no need to use a microcontroller and therefore both the circuit volume and the final cost of the project will be less. Due to the innovation in this project, we use the third method to use the module and its planning.

5. Direct Programming of ESP8266 Module Processor

Utilizing the features to have a smart home has always been an interesting issue, and engineers have created several solutions for this purpose during different periods of technology development. Smart home is a home the residents of which can adjust and control their electronic equipment remotely. In order to create smart homes, it is necessary to design, develop, and integrate hardware and software systems. Arduino is one of the hardware platforms that plays an important role in the design and development of smart homes today. The platform is a single-board microcontroller designed to make it easier to produce applications that interact with objects or the environment. One of the most widely used cases in homes is electrical multi-outlet; in this research and with the help of Arduino platform, we tried to make it smart so that we could control, turn on and off plugs through Bluetooth technology and also developed software installed in smartphones with Android operating system [5].

Using the Arduino to program ESP8266 Modules: there are several ways to program the module processor directly. Some of these methods have special software programming language. Because programming in the Arduino IDE environment is in C programming language and most people are familiar with this language and also the environment of this program is user friendly, we chose this software to program our module. To do this, the following steps are taken:

First, we download and install the latest version of Arduino IDE from the website (www.arduino.cc). Then we enter the Arduino IDE environment and click on the File tab to enter the Preferences section. Next, we Copy-paste

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the following link in the Additional Board Manager URLs box and click OK.

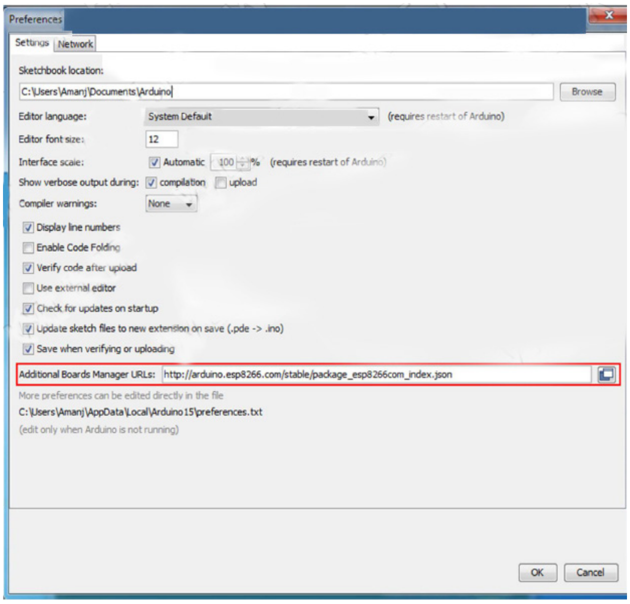

Figure 1. Arduino IDE environment

From Tools tab, we enter the Board submenu, then enter the Board manager and find the ESP8266 package, and then install it. This package is about 150 MB in size. Then we wait for the package to be fully installed.

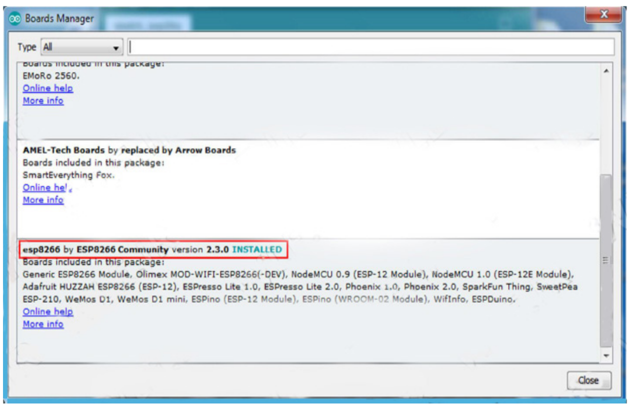

Figure 2. Activation of ESP8266 package in Board manager environment

6. Changing the settings to program the ESP8266 module

After the installation of the package, whenever we want to upload the code on the module, we must make the settings in the Arduino IDE according to the images below. These settings include:

(1) Select the board on which the program is to be uploaded.

(2) The volume of the baud rate of the board.

(3) The COM port number of the converter.

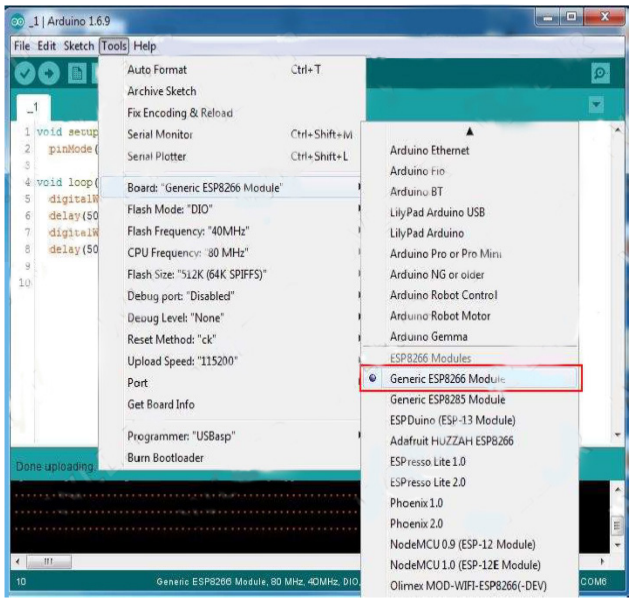

Figure 3. The settings for programming ESP8266 module

Change other settings in the Tools section according to the image below (we use the default settings without change).

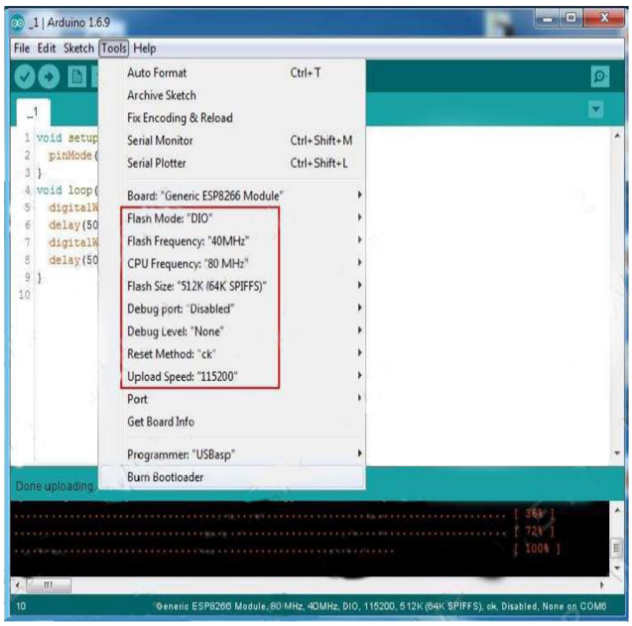

Figure 4. The settings for programming ESP8266 module

The module is now ready to be programmed by our software.

6.1 Programming

To program the module, we must first put it in Flash mode. To do this, when the board is off, we need to shorten the Flash section on the board with the jumper specified below, i.e. connect the two pins together.

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Figure 5. Technical schematic of the location of the settings related to Flash mode

Then we need to connect the USB to TTL converter to the board. To do this, we need 3 pins TX, RX, and GND from the converter. We connect these 3 pins of the converter to the pins of the program board section as shown below.

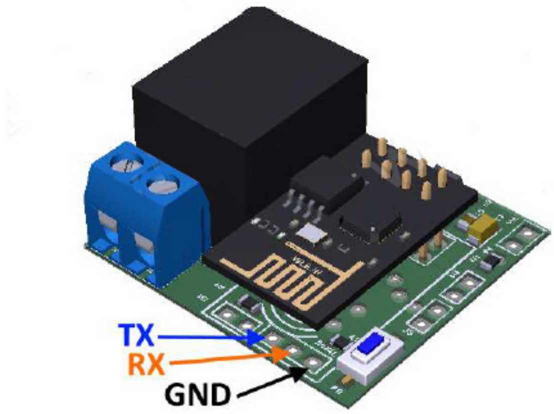


Figure 6. Technical schematic of the settings for the USB to TTL converter

Now we have to apply the board power supply. We use 5V DC voltage for power supply and connect the positive and negative power supply pins to the board as shown below.

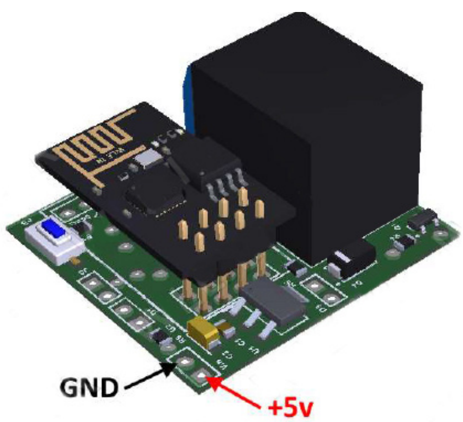


Figure 7. Technical schematic of the location of power supply settings

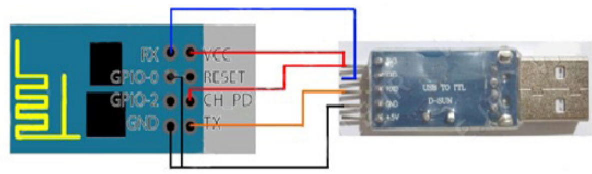
Now, we reset it using the reset key on the board to enable the Flash mode. Then we open the program and make the settings inside the Ardino IDE according to the above description. Next, we select the COM port number assigned to the converter from the Port section and click on Upload to program the software on the board.

The important point here is that in order to execute the code uploaded on the board, the jumper used to go to Flash mode must be removed and then the board must be reset to remove the module from the program mode.

6.2 Steps to Install or Update the Module Firmware

If we fail to upload the program to the ESP8266 module, we must reinstall the firmware. To do this, the following steps are taken:

(1) The module we purchased may not have a firmware installed on it at all, or the firmware may be outdated. According to the following steps, we can install or update the firmware:



Converter	module
VCC	3.3v
GND	GND
TX	RX
RX	TX
GPIO0	GND
CH_PD	3.3v

Figure 8. Steps to install or update the module firmware

Another point is to connect the GPIO base of the module to GND. The grounding of this base causes the module to go into program mode.

Note that the converter used is the PL2303 model and the module used is ESP8266-01, the first version of this module.

Note that all versions of the module can be used. The only difference is that some modules have different wiring. For example, in modules where more GPIOs are available, the GPIO15 pin must also be grounded.

(2) We connect the converter to the computer and after the converter is detected by the computer, we assign a COM address to it and run the file esp8266_flasher.exe and then enter the Com Port of the converter in the software and also Click on BIN to open the v0.9.5.2 AT Firmware.bin file to load the software.

 DOI: https://doi.org/10.30564/ese.v2i2.2464

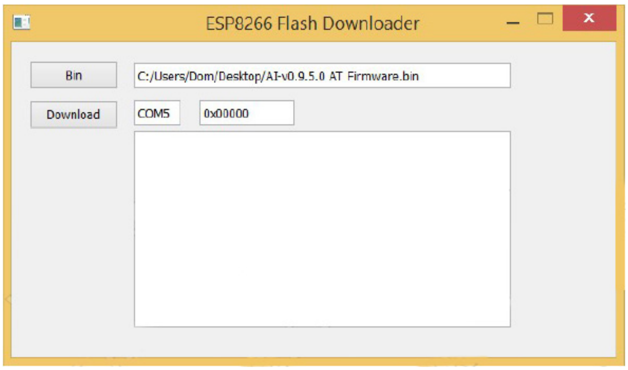


Figure 9. Installing the firmware

(3) We click on Download to install the firmware on the module and wait until the end of the installation.

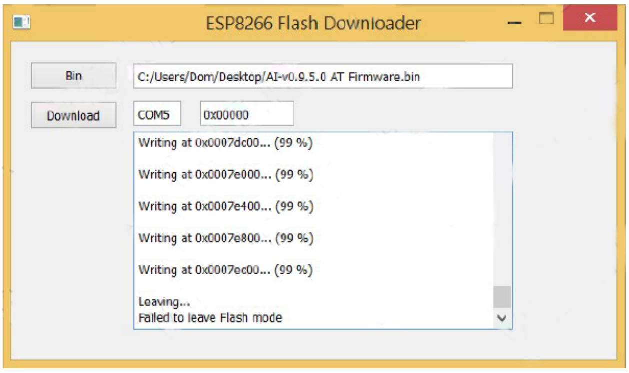


Figure 10. Installing firmware on the module

We must pay attention to 3 points:

(1) Failed to leave Flash mode message has no effect on the proper installation of the firmware on the module. After completing these steps, by removing the GPIOO pin from the ground and resetting the module, we can exit Flash mode.

(2) Failed to connect message means that we have not selected the converter COM port correctly.

(3) After completing the installation, the module settings such as baud rate may change, which can be found by testing the module (usually between 9600-115200).

7. Conclusion

Regarding the disadvantages and limitations of conventional and smart outlets, we attempted to introduce the innovative safe outlet design in the market. The features that can be listed for this design are as follows:

(1) Control of all devices that work with AC power directly and without any interfaces and converters

(2) No need for modems, internet or routers for remote control

(3) Ability to control the devices through the Android application or the web page

(4) Ability to convert old electrical outlets to smart sockets without changing the wiring and eliminating the exorbitant costs of smartizing

References

[1] Research and experiments performed by the authors Dr. Mohammad Taghipour and Mohammad Vaezi in 2019-2020.

[2] Aghaei, Mohammad Hassan, Hojjatollah Khajeh Salehani, Design and construction of sockets with the aim of reducing energy consumption and increasing safety in the building, the 4th National Conference on Electrical and Computer Engineering of Distributed Systems and Intelligent Networks and the First National Conference on Medical Engineering, Kashan, 2017.

[3] Rezaei, Hadi and Majid Fooladian. Wi-Fi smart socket with energy management capability, 2nd International Conference on Applied Research in Electrical and Computer Science, Ardabil, Pars Abad University of Applied Sciences 1- Institute of Electrical Industry, 2018. https://www.civilica.com/Paper-ICSCE02-ICSCE02_015.html

[4] Hassanzadeh Alireza, Sanei Mohammad. Design and implementation of wireless power transmission system for low power applications. Iranian Journal of Electrical and Electronic Engineering.

[5] Islami, Mehdi, Mojgan Shafiei Jam. Design of smart sockets for smart homes with the help of Arduino platform, National Conference on Science and Technology of Electrical Engineering, Computer and Mechanics of Iran, Tehran, Institute for Knowledge Development Conferences And Technology Sam Iranian, 2016. https://www.civilica.com/Paper-UTCONF01-UTCONF01_272.html

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ARTICLE

Design and Construction of A Single-Phase Power Factor Meter

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ABSTRACT

It is known that the power consumption and efficiency of an equipment owes directly to its power factor. The lower the power factor of the equipment the more the energy consumption of such equipment and vice-versa. Hence, the need to develop an equipment to measure accurately the operating power factor of domestic and industrial equipment and appliances [1]. The operating principle of this power factor meter design is based on Zero Crossing detection principle, the principle is utilized using Arduino Nano, instrument transformers, LM324 operational amplifier, generic resistor, generic XOR Gate 7488 and 2X16LCD. The input current and voltage signal is taken by the transformers and sent to the op- amp which carries out the zero crossing detection in order to get the time difference after which the microcontroller does the calculation to determine the power factor and the deficit reactive power which is then displayed on an interface [2].

1. Introduction

There is a daily increase in the rate of power consumption which owes to the high demand of electric power for domestic, commercial and industrial use. In order to meet the demand of consumers, there is a need to increase the electric power generated, transmitted and distributed in the most efficient of ways. This will be accomplished by minimizing energy loss in the power system. Electric power is the measurement of energy transfer over time. There are various types of power at work to provide us with electrical energy [3]. Working power or real power provides the power that performs actual work on the other hand reactive power is the power needed by equipment that generates magnetic fluxs. Apparent power is the vectorial summation of the real and reactive power [4]. Power factor is the measure of how effective electricity is being consumed. Power factor is also defined as the ratio of working power to apparent power [5]. There is a large amount of current being transferred when transmitting at a lower power factor which leads to a loss in power transmitted hence the need for a suitable power factor meter in order to measure accurately the power factor at various points of the power system [6].

Measuring the power factor is something that we often need to do when dealing with AC mains circuits. Ideally, every load connected to the mains supply should have a power factor of 1, but many devices like electric motors or old fluorescent tube ballasts are inductive and have a lower power factor. To correct the power factor, usually a capacitor of suitable value is connected in parallel. But to verify that the capacitor effectively corrects the power factor, there is no other way around than measuring it [5]. It must be said that the opposite situation, even if not very frequent, is also possible: an AC load could have a low power factor due to its capacitance that could be fixed by

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adding an inductor. Again, measuring the power factor is the only way to make sure we did a good job. So, it is very important to measure power of a system before we can know whether the equipment needs power factor improvement or not and also power consumption of any equipment, household, or an industry can be determined by measuring the power factor of the equipment.

2. Materials and Methods

The methodology of this research work is divided into 5 stages. (1) Power Stage (2) Load Stage (3) Zero Crossing Detection Stage (4) Computation Stage (5) LCD Display. Fig 1. illustrates the whole process in a block diagram.

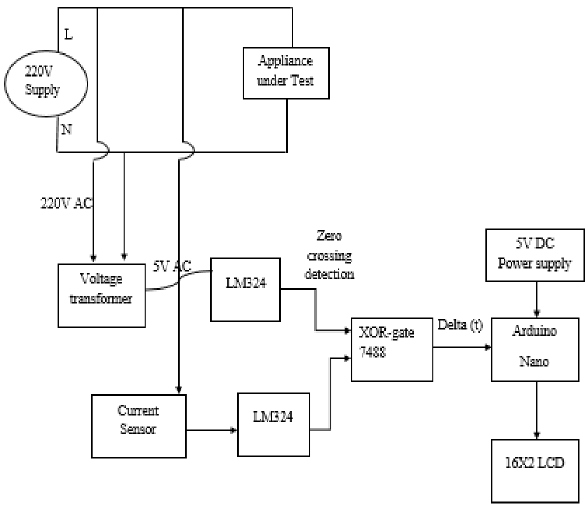

Figure 1. Block diagram representation of methodology

2.1 The Power Stage

Figure 2 shows Power supply unit. Power stage comprises of the AC side and the DC side. The 50Hz 220V/240V supply coming from the socket outlet into the design is converted to 5VDC which can easily be handled by micro controller. For the purpose of this design 5V AC to DC converter was used. Also, the incoming 50Hz, 220V AC from the AC source is sent through voltage transformer which step it down to 5Vac, this is then sent to zero crossing detection stage through first LM358 op-amp

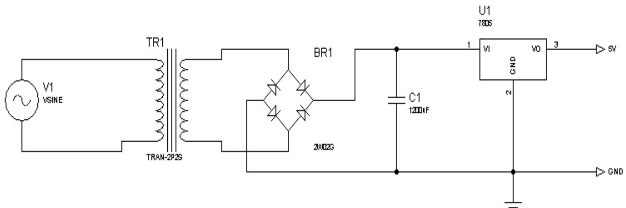

Figure 2. Power Supply Unit

2.2 Load Stage

This stage receives the load in which the power factor is to be measured using the instrument. The main component used in this stage is current transformer. The load is connected to the instrument through current transformer. The input current signal is gotten using a current transformer and sent to the second LM358 op-amp.

2.3 Zero Crossing Detection Stage

This stage comprises of two operational amplifiers which is tagged the first and the second LM358 op-amp. At this stage calculation of the phase lag between the voltage and current signal gotten from power and load stage is done, two detectors (LM324) are used to find the arrival instance of each signal. Then the difference in the arrival instance calibrated to angle gives the phase angle lag. The LM324 IC is used as the comparator circuit to function as zero crossing detector.

2.4 Computational Stage

This stage comprises of XOR gate (4030), Arduino Nano and 16X2 Liquid-crystal display. (LCD). Both signals from Zero crossing detectors is sent to the XOR gate where computational comparison between the current and voltage is done. The output signals from zero crossing detectors are in analogue form, these signals are converted to digital signal that Arduino can work with. XOR gate produces output only if there is phase difference in the two signals. The working principle is illustrated in Table 1.

Table 1. Working Principle of XOR Gate (4030)

SIGNAL A	SIGNAL B	OUTPUT
1	0	1
1	1	0
0	0	0
0	1	1

The information gotten is sent to Arduino Nano for calculation of the phase angle (Θ) and the corresponding power factor using cos(Θ) and the resulting power factor and phase shift is the displayed by 16X2 Liquid- crystal display.

The information gotten is sent to Arduino Nano for calculation of the phase angle (Θ) and the corresponding power factor using cos(Θ) and the resulting power factor and phase shift is the displayed by 16X2 Liquid- crystal display.

2.5 LCD Display

For the display of the designed power factor meter, LCD

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16x2 JHD162A is selected due to its voltage compatibility and ease of connectivity with Arduino Uno [7]. The output interface circuit between Arduino and LCD display is shown in Figure 3, using resistor and potentiometer to adjust the LCD brightness.

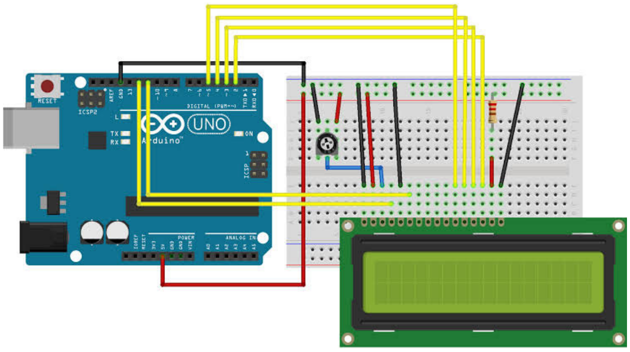


Figure 3. Output Interface between Arduino and LCD display

3. System Assembly and Results

The implementation of this project focuses on the hardware construction and the implementation of the firmware on the hardware.

Hardware Construction

(1) Assembly of Component

After selecting the components as described in the methodology section of this project, I then proceed to assemble them on a Vero board following the schematics developed in chapter three. Components placed on the board were reinforced with soldering led to ensure the copper lines could withstand the current. The number and size of components determines the size of the Vero board and the allowance between them. The step taking in this procedure include:

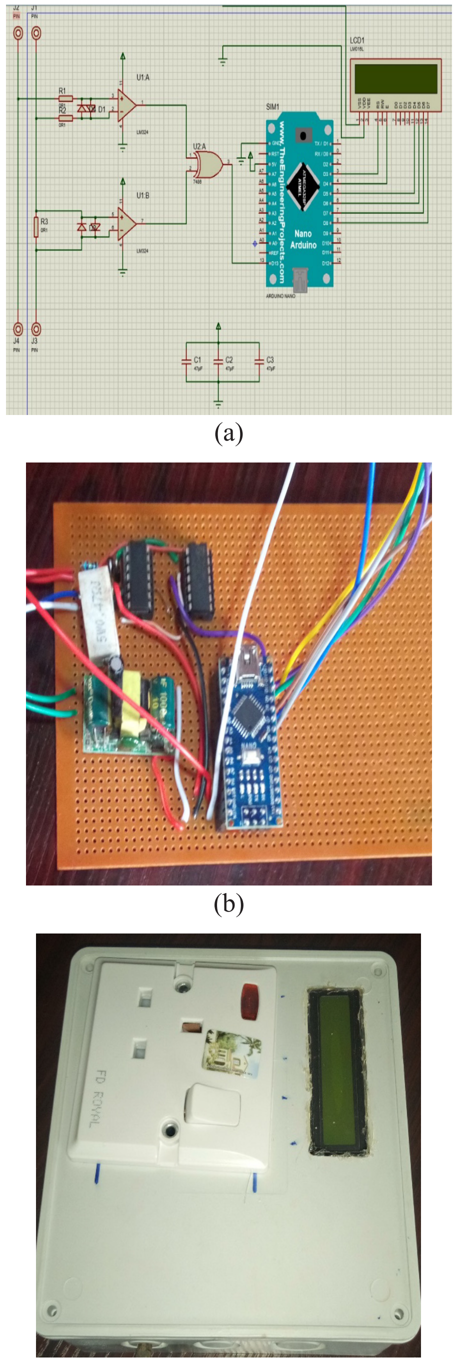
(1) Drilling the Vero board to the preferred size of the arrangement used.

(2) Thinning the components led to the required length.

(3) Arranging the components on the Vero board.

(2) Soldering of Components and Packaging

Soldering involves the joining of the conductors or components terminals to the circuit board by means of soldering iron and soldering lead. This process was carried out after the terminals of the components have been thinned and tested. The construction of the Arduino based power factor meter was done as designed in the methodology section. The tools and equipment used in designing the Testbed The tools and equipment used in designing the hardware include; cutters, long nose plier, soldering iron and lead, lead sucker, screw drivers/ precision set, drilling machine, multimeter, veroboard, PVC (or insulated) cable and jumper wires, razor blade and power supply.

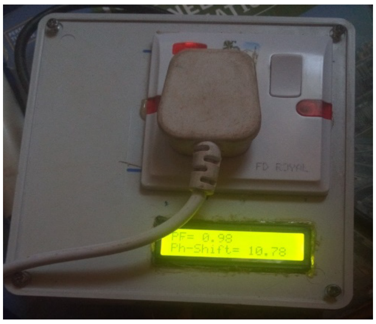


(a) (b) (c)

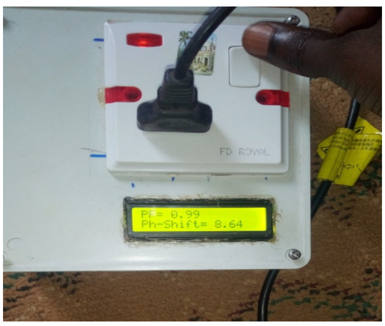
Figure 4. Circuit Design on Proteus (b) Circuit on Veroboard (c) Constructed Power Factor Meter

After every objective have been executed. The constructed power factor meter was tested by measuring the power factor of some loads whose results were compared with the standard power factor of the loads. Figure5a shows the load being measured which is a standing fan and Figure5b shows the measured power factor of the load on the meter. Figure5c shows the power factor reading of a rechargeable lamb.

(a)



(b)



(c)

Figure 5. (a) Power factor meter measuring the power factor of standing fan (b) Showing the power factor reading of standing fan (c) Power factor reading of Rechargeable Lamp

The comparison of the power factor of the loads measured and the standard power factor of the certain loads is shown in the Table 2.

4. Conclusion

After series of test, it was discovered that the operating power factor of a load depends on the type of load being measured either inductive or resistive load. The values of the power factor gotten is close to the standard power factor of the load. However, due to human errors the accuracy might be affected.

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References

[1] M. Abdul-Karim, D. Boghosian. Digital power factor design based on binary rate multiplicatio techniques. Journal of IEEE Transaction on Instrumentation and Measurement, 2002, 20: 51-84.

[2] K. Yasin, M. M. Yusuf. Automated power factor correction and energy monitoring system. International Journal of Electronics, 2007: 5-11.

[3] T. M. Chung, H. Daniyal. Arduino based power meter using instanteneous power. ARPN Journal of Engineering and Applied Science, 2015: 10-21.

[4] S. Ranaj, N. Miah, H. Rahman. Automatic power factor improvement by using microcontroller. Global Journal of Research in Engineering, 2013: 4-9.

[5] K. A. Hamad. Microcontroller based digital power factor and phase angle. IOSR Journal of Electrical and Electronics(IOSR-JEEE), 2016: 1-2.

[6] A. Biswes. Power factor measurement and correction using digital controller implemented on FPGA. International Journal of Microelectronics Engineering (IJME), 2015: 154-541.

[7] 16x2 LCD display module," Circuit Digest, 2019. [Online]. Available: https://circuitdigest.com/article/16x2-lcd-display-module-pinout-datasheet [Accessed 24 October 2019].

Table 2. Showing the measured power factor reading of tested load and standard power factor reading as given by manufacturer

S/N	LOAD TESTED	STANDARD POWER FACTOR	MEASURED POWER FACTOR
1	Television	0.93-0.96	0.95
2	Rechargeable lamp	0.98-1.0	0.99
3	Drilling machine	0.80-0.89	0.89
4	Blender	0.79-0.81	0.82
5	DVD	0.93 -0.96	0.98
6	Printer	0.80-0.82	0.85
7	Soldering iron	0.90-0.96	0.92
8	Standing fan	0.94-0.96	0.98
9	Iron	0.91-0.96	0.92

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ARTICLE

Design and Economic Analysis of a Grid-connected Rooftop Solar PV System for Typical Home Applications in Oman

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ABSTRACT

This paper presents a techno-economic investigation of an integrated rooftop solar PV system for typical home applications in Oman that can reduce the power consumption from the grid and export excess PV generated power back to the gird. Since renewable energy systems design technically depends on the site, this study selects a typical two-story villa (Home), in a site Al-Hamra, Oman. Temperature is one of the critical parameters in this design as it varies widely over the day and from one season to another in Oman. With the effect of temperature variation, the PV system has designed using system models for the required load of the home. The design process has included two main design constraints, such as the available rooftop space and the grid-connection availability for the selected home. This research also evaluates the economic feasibility of the design system considering the energy export tariff as per the Bulk Supply Tariff (BST) scheme in Oman. The design outcome reveals that the designed PV system can supply the load energy requirement in a year. In addition, the rooftop solar PV system can sell surplus energy back to the grid that generates additional revenue for the owner of the system. The economic performance indices such as payback period, internal rate of return, net present value, and profitability index ensure the financial feasibility of the designed rooftop solar PV system for the selected home.

1. Introduction

The negative impacts of the fossil fuel-based power generation and quick depletion of fossil fuel reserve are the key factors of increasing renewable-based power generation applications and integration. The renewable energy sources offer advantages, such as they are locally and freely available, sustainable, and environmentally friendly. On the contrary, the load demand around the world is significantly increasing every year. Therefore, significant momentum has seen in developing modern power network infrastructures such as smart grids and microgrids using renewable energy sources over the last decades [1]. The primary source of generating electrical power in Oman is natural gas. In addition, the power demand in Oman is increasing by around 6%, and the emitting amount of harmful gas like CO_2 that comes out from the fossil fuel-based generation is undoubtedly high. Over the last 14-year period (2005-2018), the growth rate of annual average demand was 9%, while the growth rate of the annual average peak demand was 7.5%. Moreover, over the next 7-year (2019-2025), the expected growth rate of annual average

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and peak demand is 5% [2]. Therefore, the Sultanate of Oman is currently integrating alternative green energy sources to contribute to electricity production, besides fossil fuel-based generations.

Literature reveals several investigations on designing rooftop PV system that supplies power either to the home load or to the utility grid depending upon the need. Authors in [3] present economic analysis considering the present Feed-in tariff scheme for grid-interactive rooftop PV systems for home applications in Turkey. The study suggests providing more incentives to deploy PV systems as it reveals attractive economic performance indices. Researchers in [4] have investigated the economic performance of grid-interactive home PV systems using an integrated economic adoption model that comprises of economic evaluation, analysis of profitability and sensitivity, and the probability distribution of levelized cost of electricity. The design and techno-economic study of a grid-interactive solar PV system design have been presented in [5]. This study reveals that the solar PV system application in Indonesia with Feed-in tariff scheme has a shorter payback period than the system without such a scheme. S. Yoomak et al. investigates the economic performance of rooftop PV system for various locations of Thailand considering different sizes and technologies of PV arrays [6]. It unfolds that the PV system with a capacity of 10 kW or less is economically viable if it installs with the Feed-in tariff scheme. Authors in [7] have presented the design and economic performance study of a rooftop PV system using PV*SOL for a university building in Turkey. The design outcomes reveal that PV system can supply 13.2% of the building energy consumption annually, and the system can reach the breakeven point after 12.52 years. Reference [8] has demonstrated feasibility analysis of a grid-connected PV system, which indicates the cost competitiveness of the rooftop PV system with the support mechanism from the government and utility owners, such as Feed-in tariff scheme. Although the residential PV system shows satisfactory economic performance using Feed-in tariff as found by several researchers, reference [9] has presented an unsatisfactory economic performance of a residential solar PV system that considers multiple demands charge tariff. Such performance may arise due to the low solar irradiation or high cost of the technologies in the local market. Furthermore, economic analysis, optimal size and location, and hybridization of PV technologies for off-grid applications have been investigated and presented in [10,11].

In Oman, about 97.5% of the total electricity generation comes from natural gas. Diesel is currently using to generate electricity for rural and remote areas. The Sultanate of Oman has the compelling potential of utilizing solar and wind energy resources for renewable power production. The solar power potential in Oman is such that electricity production from this source can serve the country's power demand in addition to the significant export ability [12-15]. To these effects, the Sultanate is currently integrating renewable-based power generations in various scales for different applications. For example, the Authority for Electricity Regulation (AER), Oman has introduced Sahim I and Sahim II schemes that create the opportunity to integrate rooftop solar photovoltaic (PV) systems. The scheme Sahim I permits customers like large home and commercial premises owner to install and connect small-scale grid-interactive PV system with their own cost. This scheme also allows the system owner to export excess energy to the grid and receive pay back as per Bulk Supply Tariff (BST) [16]. Latter, Sahim II introduces in order to promote the large-scale implementation of the solar PV system. It aims to implement the small-size grid-interactive PV system for about 250000 rooftop installations, where the system cost comes from a funding agency and the premises owner upon an approved contract between the parties [16].

The Ecohouse at the Sultan Qaboos University in Oman is an example of an on-grid rooftop PV system application. This PV system has installed capacity of 20.4 kWp [17]. The other Ecohouse located at the campus of Nizwa University in Oman, which has a rooftop PV system with an installed capacity of 20 kW [18]. PV-system in both Ecohouses supply excess energy to the grid after meeting the house load in the daytime. However, the power requirement for the Ecohouses during the nighttime comes from the grid. In these projects, the designed houses are ecofriendly, which may have different characteristics compared to the typical Omani houses. A rooftop PV system for an office building has presented in [19]. Moreover, the economic analysis of these studies shows a more extended payback period that is not encouraging. Such economic results may arise due to the absence of any incentive or consideration of the Feed-in tariff scheme. This study illustrates the design and economic performance investigation of a rooftop PV system design for a typical Omani house. The economic evaluation in this study includes the current energy export tariff as per the Bulk Supply Tariff (BST) scheme that results in an encouraging economic performance compared to the study presented in [18].

2. Research Methodology

2.1 Home Site Selection and Energy Consumption

In this study, a typical home, two-story villa, has selected

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to design the rooftop PV system. The home locates in the Wilayat Al-Hamra (23°07′00″N 57°17′35″E) in the Dakhiliyah Governorate in Oman. The available rooftop area in this selected home is 300 m^2, and around 40 m^2 is reserved from this area for the tanks and other uses; as a result, the total available area for the PV system is 260 m^2. Moreover, the Mazoon Electricity Company, Oman, currently supplies the house load.

Designing the PV system requires energy consumption by the selected home. The energy consumption data for the home load is obtained from the Mazoon Electricity Company, Oman. Figure 1 shows the home energy consumption for each month for the year 2017. The total load consumption for the selected home is 37.23 MWh/year. The average energy consumption by the home load is 102 kWh/day. The home load consumes above the average level of energy consumption during May, June, July, August, September and October months in a year, while the energy consumption during the other month is below the average level. It also reveals that the home load consumes maximum energy in July. It is because July is one of the hottest months in a year and people occupancy at home likely higher. The lowest amount of energy consumption is in February because this is one of the coldest months in a year. Table 1 shows the frequently used list and quantities of devices and home appliances for the selected home. However, not all the devices and appliances are operating at the same time. All the devices and appliances operating at the same time requires the peak energy demand of 137 kWh, which does not practically happen. Therefore, design rooftop solar PV system aims to produce an average daily energy of 102 kWh.

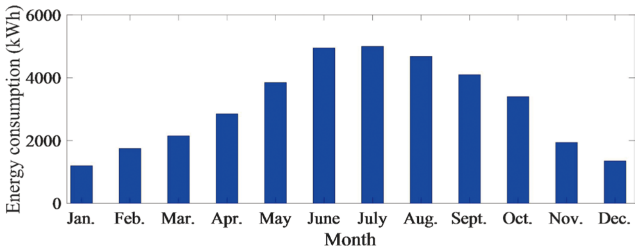

Figure 1. Monthly energy consumption by the load of the selected two-story villa

Table 1. Detailed of home appliances used in the selected two-story villa

Devices	Type/Specification	Quantity	Rated power (W)
Air conditions	1.5 ton 2 ton	5 2	1510 1850
Tube light	4 feet 2 feet	35 11	40 24
Fans	Ceiling Fans Exhaust Fans (20 cm) Exhaust Fan (25 cm)	14 6 3	100 275 305
Water Cooler	-	1	200
Freezer	-	2	300
Heaters	100 Liters 80 Liters	5 4	1700 1300
Washing Machine	-	1	2500
Televisions	-	4	40
Iron	-	1	1000
Chargers	-	5	10
Water pressure	-	2	250

2.2 Solar Insolation and Temperature

Site solar irradiation and temperature directly influence the PV system output and its conversion efficiency. The accuracy of these data is essential in designing the solar PV system. The data for the Wilayat Al-Hamra for one year (2017) has been collected from the Directorate General of Meteorology and Air Navigation Department, Oman. Figure 2 illustrates the monthly average solar irradiation at the site of the selected home. The annual average solar irradiation for this site is 5.80 kWh/m^2/day. The maximum solar insolation is 7.29 kWh/m^2/day in May while the minimum solar insolation is 4.14 kWh/m^2/day in January for this site. The data analysis also indicates that the peak sun hour for the selected site is 5.8 hours.

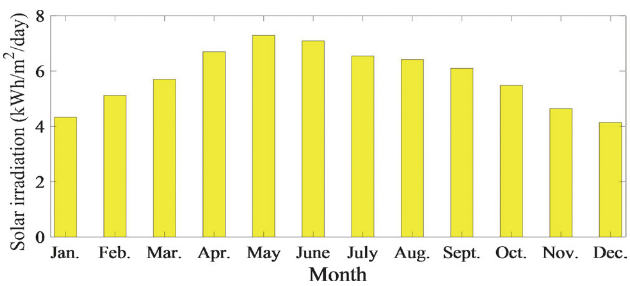

Figure 2. Monthly average solar irradiation for the selected home at the Al-Hamra site in Oman for the year 2017

Figure 3 demonstrates monthly average temperature variation at the Al-Hamra site in Oman. The highest average temperature observed as 35.9^{0}C in July. Furthermore, the lowest average temperature noticed as 19.6^{0}C in January. The hottest months for the selected site are May, June, July, and August, while the coldest months are January and December. The average temperature for each month of the year varies from 19.6^{0}C in January to 35.9^{0}C in July. It indicates a broader range of variation in temperature each day. Such variation in monthly temperature is sarcastic in designing solar rooftop PV system as it reduces the conversion efficiency of the PV arrays.

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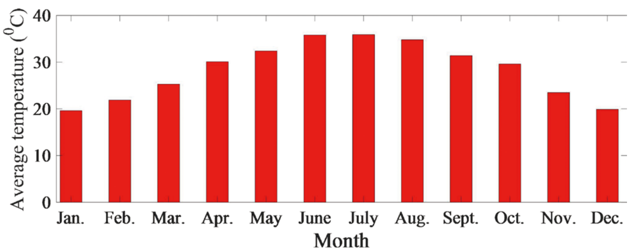

Figure 3. Monthly average site temperature data for the year 2017

Table 2. Permitted tariff (OMR/kWh) for residential consumers

Slabs	0-3000 kWh	3001-5000 kWh	5001-7000 kWh	7001-10000 kWh	Above 10000 kWh
Cost/ kWh	0.01	0.015	0.02	0.025	0.030

2.3 Tariff Structure

Currently, in Oman, the residential customers pay their electricity cost based on the defined slabs, as shown in Table 2 [20]. As per the Table 2, the owner of the selected house pays 0.01 OMR/kWh until the consumption 3000 kWh, while 0.015 OMR/kWh pays for the consumption between 3001-5000 kWh. However, if the selected house installs PV system, the system owner can export power to the grid as per the Bulk Supply Tariff (BST) structure presented in Tables 3 and 4 [21]. BST, a component of Cost Reflective Tariff (CRT), charges the cost of capacity production of electricity demand requirement for the customers at different period [22]. BST scheme is different for the Main Interconnected System (MIS) and the Dhofar Power Systems in Oman. It is because of the different underlying charges. The selected home in this study follows the BST scheme of MIS. The BST has two main components, such as BST rate band, and BST rate. BST rate band defines peak or off-peak periods for different days in a week. Table 3 shows the BST rate band that has four rate bands such as off-peak, night-peak, weekday day-peak, and weekend day-peak. Moreover, it defines the periods, such as 12:00 to 15:59 from Sunday to Saturday as the weekday day-peak; while 2:00 to11:59 and 16:00 to 21:59 define as the off-peak period for the entire week.

Table 3. MIS rate bands of the BST

Rate Band	Off-peak	Weekday day-peak	Night-peak	Weekend day-peak
Period	2:00 - 11:59 16:00 - 21:59	12:00 - 15:59	22:00 - 1:59 (Next day)	12:00 - 15:59
Days of week	Each day	Sunday - Thursday	Each day	Friday and Saturday

Table 4 represents the charge of electricity consumption for different periods along with specific months. It reveals that the charge of electricity consumption is higher during weekday day-peak from May to July because the load demand is significant at these months and defined period. In contrast, the lowest cost of electricity consumption is in between November and March. Table 4 also shows that the energy cost for some months does not depend on the period. It remains the same throughout the month, such as in April. It is important to note that MIS or Mazoon Electricity Company is charging to their consumers as per the BST since they are the energy producer, supplier or distributor. Similarly, any customer who may own the solar rooftop PV system, this customer can charge the Mazoon Electricity Company as per the BST for exporting energy to the grid. The economic analysis of the designed solar rooftop PV system incorporates this energy export tariff in this study.

Table 4. Per kWh charge (OMR/kWh) as per the BST

Months	Off-Peak	Week-day-Peak	Night-Peak	Week-end-Peak
January-March	0.012	0.012	0.012	0.012
April	0.014	0.014	0.014	0.014
May-July	0.016	0.067	0.024	0.038
August-September	0.015	0.026	0.021	0.019
October	0.014	0.014	0.014	0.014
November-December	0.012	0.012	0.012	0.012

2.4 Sizing and Design Model of the System

The DC power output of the PV array is determined as [23]

$$P_{dc} = \frac{E_{load}}{D_f H_{psh} N} \tag{1}$$

where P_{dc} is the PV power production in kW, E_{load} is the annual energy consumption by the home load kWh/year, D_f is the total derating factor for both the temperature and other subsystems, H_{psh} is the peak sun hour, N is the total number of days in a year.

To reflect the temperature variation effect on the PV generated power, the PV cell temperature, T_{cell} is calculated as [24],

$$T_{cell} = T_a + \left(\frac{T_{NOCT} - 20^0 C}{S_{NOCT}} \right) \times S_{site} \tag{2}$$

where T_a is the site temperature in ^{0}C, S_{site} is the average solar intensity in kW/m^2, S_{NOCT} is the solar intensity

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at standard testing condition (STC) in kW/m^2, T_{NOCT} is the Normal Operating Cell Temperature (NOCT) of the PV module in ^{0}C at STC.

The decrement in module output power due to the site temperature variation as a percentage of the maximum power is calculated as

$$P_{\text{mod}} = \beta \times \left(T_{cell} - 25^0 C\right) \tag{3}$$

where β is the reduction in module output power for per ^{0}C temperature change in %/^{0}C. The derating factor because of the temperature variation, $D_{f,\,temp}$ is calculated as

$$D_{f,temp} = 1 - P_{\text{mod}} \tag{4}$$

The total derating factor, D_f is calculated as

$$D_f = D_{f,temp} \times D_{f,comp} \tag{5}$$

where $D_{f,\,comp}$ is the derating factors due to the DC rating on the PV module nameplate, inverters, module inconsistency, AC and DC wiring, and shading [23].

The required area for the solar PV array system is calculated as

$$A_{pv} = \frac{P_{dc}}{\alpha S_{STC}} \tag{6}$$

where A_{pv} is the required area for the PV array in m^2, α is the module efficiency that is available in the manufacturer data sheet.

The number of modules, n_{mod} required for the PV panel is determined as

$$n_{\text{mod}} = \frac{A_{pv}}{A_{\text{mod}}} \tag{7}$$

where A_{mod} is the required area for each PV module and it is available in the manufacturer data sheet.

In order to determine the PV system output voltage in an acceptable limit at the inverter input, the effect of temperature variation incorporated to calculate the PV module output voltage. With the effect of site temperature variation, the voltage at the PV module output is computed as [25]

$$V_{mo} = V_{mo,\text{STC}} \times \left(1 - \kappa\left(T_{cell} - 25^0 C\right)\right) \tag{8}$$

where $V_{mo,STC}$ is the voltage at the module output at STC, κ is the decrement in voltage at the module output for per ^{0}C temperature variation in %/^{0}C.

2.5 Economic Performance Model

This section presents economic performance indices models to evaluate the economic performance of the designed solar PV system. Such economic indices are the payback period, net present value, internal rate of return, and profitability index [26].

Payback period defines the period that is required to get back the invested funds into a project. This parameter is simple to find, yet, it provides some judgment on the economic value of the project [23,26]. The payback period is calculated as

$$\text{Payback period (PP)} = \frac{\text{Initial capital cost}}{\text{Annual cash inflow}} \tag{9}$$

The net present value (NPV) determines as the difference between the current value of the cash inflows and outflows related to the investment over a period. This economic index considers the time value of money and overcomes the drawback of the payback period index. The positive value of this parameter indicates the project profitable, whereas the negative value indicates the project in a net loss [23,26]. NPV is determined as follows

$$\text{Net present value (NPV)} = \sum_{n=1}^{N} \frac{C_n}{\left(1+r\right)^n} - C_i \tag{10}$$

where C_i is the total initial cost, C_n is the net cash flow for the period n, r is the discount rate, and n is the number of years.

The internal rate of return (IRR) represents the discount rate for which the net present value turns to zero. Therefore, equation 11 can be derived from equation 10 to calculate the IRR for an investment. The higher IRR indicates the faster recovery of the invested funds and vice versa.

$$0 = \sum_{n=1}^{N} \frac{C_n}{\left(1+IRR\right)^n} - C_i \tag{11}$$

The profitability index (PI) defines as the ratio between the NPV and the initial investment cost [26].

$$\text{Profitability index (PI)} = \frac{\text{Net present value}}{\text{Initial investment cost}} \tag{12}$$

3. Results and Discussion

This section discusses the implementation of the research methodology of designing and economic analysis of the rooftop solar PV system presented in the preceding section. The Matlab software package has been used to implement the method discussed. It also demonstrates the outcomes of the research. Moreover, the energy export tariff as per the BST has utilized to calculate the monthly return by the designed system. The Phono Solar PV module (PS300M-24/T) and the inverter (Solis-25K) have chosen, and their detail specifications have been utilized from the manufacturer datasheet.

3.1 Design of Rooftop Solar PV System

The rooftop solar PV system for a typical villa type home is designed to supply the energy requirement of the loads in the home. The total amount of energy required by the load is 37.23 MWh/year, the average daily energy required is 102 kWh for the home load, and Figure 1 referred to the monthly average load demand for the selected home. The designed solar rooftop PV system ensures the delivery of the total energy requirement of the selected home.

With the equations 2-5, the effect of varying temperature has been incorporated in the designed solar PV system by computing the derating factor due to the site temperature variation. Figure 4 illustrates the monthly derating factors variation in a year. It indicates that the PV system output varies in a broader range due to the temperature fluctuations. The hottest months, June reveals the lowest derating factor, 0.8583. It reveals that the output of the PV system can be decreased by 14.17% from its max value in June. On the other hand, the coldest month, January reveals the highest derating 0.9650. This derating factor reveals that there is a 3.5% reduction in PV output power from its max value in January. The mean derating factor due to the temperature variation, $D_{f,temp}$, is determined as 0.9077. The mean derating factor for the other subsystems, $D_{f,comp}$ is calculated as 0.77 and obtained from the Reference [25]. With the effect of temperature variation and other system components together, the total derating factor, D_f, has found as 0.6989 using equation 5.

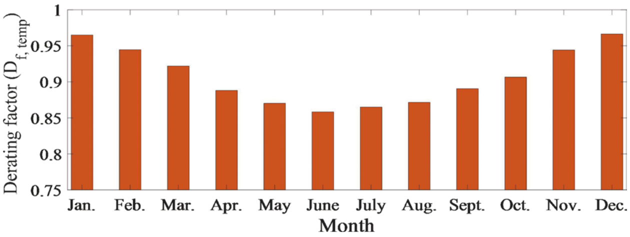

Figure 4. Monthly derating factor variations for the temperature variation

The DC power P_{dc} for the designed solar PV system has found to be 25.2 kW using equation 1. The required area to install this 25.2 kW PV system has calculated considering the module efficiency of 15.46%, as per the manufacturer datasheet, and 1 kW/m^2 solar intensity at STC. Equation 6 calculates the required area for the rooftop solar PV system as 163 m^2. Each module requires an area of 1.96 m^2 as per the manufacturer datasheet. Equation 7 calculates the number of modules required for a 25.2 kW PV system, and it is found as 84.

Table 5. Output voltage of the module considering the effect of temperature

Weather conditions	Monthly average temperature	PV cell temperature, T_{cell}	Module rated output voltage at STC	Output voltage of the module considering temperature effect	Module numbers per string
Coldest month	19.6^{0}C	33.13^{0}C	36.7 V	35.715	6 - 23
Hottest month	35.9^{0}C	57.95^{0}C	36.7 V	32.90	6 - 24

According to the manufacturer datasheet, the input voltage range of the selected inverter is 200V to 800V, which has been used to find out the module arrangement in the PV system. At STC, the module rated output voltage is 36.7V. Equation 8 calculates the module output voltage considering the effect of the site temperature variation. Table 5 reveals detailed about the module output voltage and the possible arrangement of PV modules in a string for two boundary conditions, such as the hottest and the coldest month in a year. The outcomes reveal that the module output voltage reduces because of the higher PV cell temperature compared to the STC PV cell temperature for two extreme conditions. The significant reduction in the PV module voltage has observed during the hotter months of the year. This outcome indicates that the hottest condition is the worst-case scenario, which is a good choice to determine module numbers of the string. The module output voltage reduces due to the hottest condition to 32.90V. It suggests that the range of module numbers that are possible to connect in a string as 6 - 24. Since the rated input voltage to the inverter at the maximum power point is 600V, this study suggests constructing a sting with 17 modules in series. The designed solar rooftop PV system requires 84 modules. Thus, the PV system layout can contain 5 strings, with a 17 modules in each string. The contribution of the short circuit current by each string can be 8.60A, which can result in a total short circuit current by the designed PV system is 43A that may present at the inverter input. Since the short circuit capacity of the inverter is 93.6A (more than 43A), it is sufficient to take over the short circuit current that may supply from the de-

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signed PV system.

Figure 5 demonstrates the monthly energy portrait of the designed rooftop solar PV system for one year. PV generation refers here to the monthly energy generation by the rooftop PV system. The monthly energy generation varies due to two main factors, such as solar irradiation variation and derating factors variation due to the change in monthly temperature. The load consumption is the energy required by the appliances and devices used in the selected home. The energy export refers here as the positive energy balance that the PV owner can sell to the grid. The energy import refers here as the negative energy that the home load consumes from the grid while the PV generation is not sufficient to serve the load.

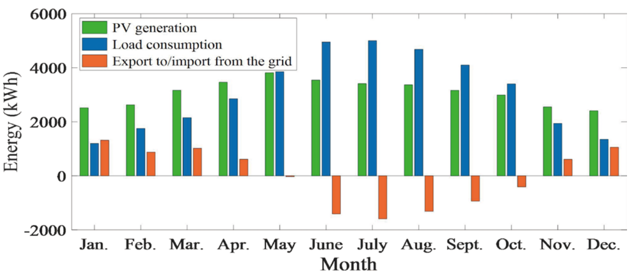

Figure 5. Energy production by the designed PV system, home load consumption and energy balance detail

Figure 5 shows that the energy required by the home load is 1198 kWh, while the energy production by the designed PV system is 2513.53 kWh in January. The surplus energy in this month is positive 1315.53 kWh. The PV system owner can export this excess energy to the grid. The rooftop solar PV system designed in this study generate surplus energy in February, March, April, November, and December. In May, the energy balance between the PV generation and the load demand is only negative 33.48 kWh, which reveals that the PV system can generate almost the same amount of energy required by the load. Figure 5 reveals that the energy equity in June is negative 1407.25 kWh. The negative energy balance indicates that the PV generation is less than the energy demand by the load. Thus, the grid requires to supply this energy demand of the load. Similarly, July, August, September, and October reveal the same energy balance scenario. Furthermore, the total energy balance by the PV system over the year is close to zero. It indicates that the designed rooftop solar PV system is sufficient to generate the load demand for the selected home. However, the time of energy export to the grid is different from the time of energy import from the grid. Such a difference can generate extra money for the PV owner if the energy sell price is higher compared to the buying price of the energy.

Figure 5 also reveals variation in PV energy production in each month because of the fluctuations in solar irradiance and the temperature-derating factor. Figure 2 has shown that the monthly average solar irradiances in May and January are 7.29 kWh/m^2/day and 4.33 kWh/m^2/day, respectively. The solar irradiance in May is almost 68.36% higher compared to January. It indicates that energy production in May would be 68.36 % higher compared to January. However, the actual energy production in May is 51.82% higher compared to January because of the rise in temperature in May. Such effect of the rise in temperature reflects in the PV system design by using the derating factor due to the temperature. Moreover, Figure 4 has demonstrated that May has a low value of the derating factor compared to January, which indicates a higher reduction in the PV output power during May.

3.2 Economic Analysis

This section presents economic performance indicators, such as payback period (PP), net present value (NPV), internal rate of return (IRR), and profitability index to evaluate the economic performance of the designed rooftop solar PV system. The renewable energy market analysis: GCC 2019 by the International Renewable Energy Agency (IRENA) reveals that the rooftop PV project implementation cost in 2018 was USD 700/kW (270.27 OMR/kW) in the UAE [27]. The start-up cost of the solar rooftop PV system of rated 25.2 kW has calculated as USD 17640 (6811 OMR). The initial cost comprises the system components and implementation costs. This study considers 0.22% of the initial cost as the operation and maintenance costs [28]. Both the initial investment and operating costs have used as the outflows cost of the study system. The inflows cost of the system comes from the cost of the energy generated by the solar rooftop PV system. The designed PV system exports 11.19 MWh/year to the grid among which 5.7MWh/year returned to the load when the PV system has no sufficient generation or during the nighttime, and directly supplies to the load is 26.04 MWh/year. The cost of energy supplies to the load and export energy to the grid combines as the cash inflows for the system. The energy export tariff presented in Tables 2 and 4 has used to calculate the cash inflows for the system [20-22]. The project lifetime is the same as the PV panel replacement period, which is 25 years.

Figure 6 demonstrates cash flows for the rooftop solar PV system without considering the discount rate. The possibility of investing in this project without the bank loan is the reason for considering a zero discount rate. Figure 6 shows the positive annual cash flow at the eleventh year, which indicates the simple payback period of this project investment. Equation 10 calculates the net present value (NPV) as OMR 1129, while equation 12 determines the profitability index as 1.66. Moreover, the internal rate of return (IRR) found as 9.65%. The economic performance indicators establish that the rooftop solar PV system is economically viable, which has a shorter payback period (11 years) and no need for borrowing money from the bank.

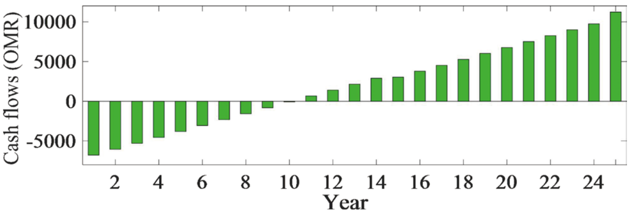

Figure 6. Cash flows for the designed rooftop solar PV system without discount rate

Figure 7 explains the performance of the cash flow for the rooftop solar PV system considering the discount rate, r = 5.5%, which has obtained from one of the Banks in Oman. The discounted cash flow analysis reveals economic performance for the solar PV system owner in case the investment made through a bank loan. Figure 7 also indicates that the positive annual cash flow in the fourteenth year, and thus the payback period is 14 years. Equation 10 calculates the net present value (NPV) as OMR 2924, and equation 12 calculates the profitability index (PI) as 0.43. In addition, equation 11 determines the internal rate of return (IRR) as 3.93%. The discounted cash flow analysis demonstrates that the payback period is high. At the same time, the net present value and the internal rate of return is low, and the profitability index is less than one. These testify that the designed rooftop solar PV system is still economically viable, even if it implements through the bank loan. However, the investor return can be slower as compared to the upfront investment by the investor or the PV owner.

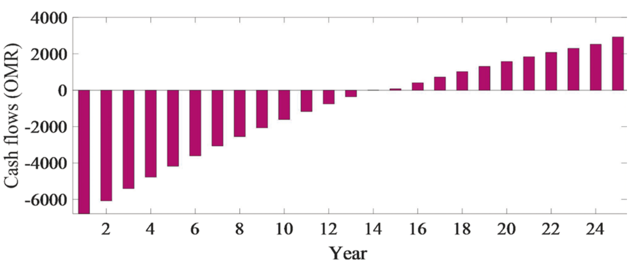

Figure 7. Cash flows for the designed rooftop solar PV system with a discount rate, r = 5.5 %

4. Conclusion

This paper has presented the design and evaluation of the economic performance of a grid-connected rooftop solar PV system for a typical home in Oman. The effect of temperature fluctuations on the PV system power generation has been incorporated in the presented design method. The result has shown that the PV output power lessens naturally because of hot weather and a broad change in temperature at the site of the selected home. The rooftop solar PV system has shown the ability to export 11.19 MWh/year to the grid and to supply 26.04 MWh/year to the load directly. The designed PV system (25.2 kW) requires 163m^2 rooftop area that satisfies the space constraint considered in the design process. It has shown that the rooftop PV system needed 85 modules that have suggested arranging in 5 strings, where each string can have 17 modules connected in series. Such an arrangement also satisfies the manufacturer specification and requirements of the selected inverter and PV modules.

The economic analysis of this study has shown that the designed rooftop solar PV system for the selected home is economically feasible and productive. The discounted payback period was found for 14 years, whereas the simple payback period was found 11 years. The net present values with and without the interest rate were found positive. Moreover, the internal rate of return with and without the interest rates were found as 9.65% and 3.93%, respectively. The performance indicators have shown that the rooftop PV system is profitable and sustainable if the investment made either with or without considering the discount rate. Investments on the rooftop PV systems can reduce the grid dependency, and can contribute to supporting sustainable development in Oman. However, some other aspects such as power quality, flicker, harmonics, and voltage profile in integrating solar PV system need to investigate for operating the efficient and effective power system network. This study has shown that the solar rooftop PV system installation under the BST scheme is encouraging, as found in other studies [8,9,12].

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References

[1] Al-Badi AH, Ahshan R, Hosseinzadeh N. Ghorbani R, Hossain E. Survey of Smart Grid Concepts and Technological Demonstrations Worldwide Emphasizing on the Oman Perspective. Appl. Syst. Innov., 2020, 3, 5.

[2] OPWP's 7-YEAR STATEMENT (2019 - 2025), Ac-

  DOI: https://doi.org/10.30564/ese.v2i2.2188

cess on July 7, 2020.
https://omanpwp.om/new/Documents.aspx?Pid=46
[3] A. C. Duman, O. Güler. Economic analysis of grid-connected residential rooftop PV systems in Turkey. Renewable Energy, 2020, 148: 697-711.
[4] O. Ellabban,A Alassi. Integrated Economic Adoption Model for residential grid-connected photovoltaic systems: An Australian case study. Energy Reports, 2019, 5: 310-326
[5] E. Tarigana, Djuwaria, F. D. Kartikasarib. Techno-Economic Simulation of a Grid-Connected PV System Design as Specifically Applied to Residential in Surabaya, Indonesia. Energy Procedia, 2015, 65: 90-99.
[6] S. Yoomak, T. Patcharoen, A. Ngaopitakkul. Performance and Economic Evaluation of Solar Rooftop Systems in Di_erent Regions of Thailand. Sustainability, 2019, 11, 6647.
DOI: 10.3390/su11236647
[7] A. N. Akpolat, E. Dursun, A. E. Kuzucuoğlu, Y. Yang, F. Blaabjerg, A. F. Baba. Performance Analysis of a Grid-Connected Rooftop Solar Photovoltaic System. Electronics 2019, 8: 905.
DOI: 10.3390/electronics8080905
[8] S. Moury, R. Ahshan. A feasibility study of an on-grid solar home system in Bangladesh. 2009 1st International Conference on the Developments in Renewable Energy Technology (ICDRET), Dhaka, 2009: 1-4.
[9] M. Zeraatpisheh, R. Arababadi, M. S. Pour. Economic Analysis for Residential Solar PV Systems Based on Different Demand Charge Tariffs. Energies 2018, 11: 3271.
[10] A. Maleki, M. A. Nazari, F. Pourfayaz. Harmony search optimization for optimum sizing of hybrid solar schemes based on battery storage unit. Available online 9 April 2020.
[11] G. Zhang, Y. Shi, A. Maleki, M. A. Rosen. Optimal location and size of a grid-independent solar/hydrogen system for rural areas using an efficient heuristic approach. Renewable Energy, 2020, 156: 1203-1214.
[12] A. H. Al-Badi, A. Malik, A. Gastli. Sustainable energy usage in Oman-opportunities and Barriers. Renewable and Sustainable Energy Reviews, 2011, 15: 3780-8.
[13] Authority for Electricity Regulation - Oman, Study on renewable energy resources in Oman-Final Report by COWI and Partners LLC, Muscat, 2008.
[14] S. AL-Yahyai, Y.Charabi, A.Gastli, S. Al-Alawi. Assessment of wind energy potential locations in Oman using data from existing weather stations. Renewable and Sustainable Energy Reviews, 2010, 14: 1428-1436.
[15] R. Ahshan, A. Al-Badi, N. Hosseinzadeh, M. Shafiq. Small Wind Turbine Systems for Application in Oman. 2018 5th International Conference on Electric Power and Energy Conversion Systems (EPECS), Kitakyushu, Japan, 2018: 1-6.
DOI: 10.1109/EPECS.2018.8443520
[16] https://aer.om/en/sahim. Accessed on July 9, 2020.
[17] Ecohouse.om: Solar Energy - Eco House Oman. Available from URL:
http://www.ecohouse.om/solar-energy/
[18] Unizwa.edu.om: EcoHouse Design @ University of Nizwa. Available from URL:
http://www.unizwa.edu.om/ecoHouse/home.php?op=en_ener
[19] M. H. Albadi, R. S. Al Abri, M. I. Masoud, K. H. Al Saidi, A. S. Al Busaidi, A. Al Lawati, K. Al Ajmi, I. Al Farsi. Designing up to 50 kW Solar PV Rooftop System. ICSGCE 2014 Conference of Smart Grid and Clean Energy, Sharjah, UAE.
[20] https://mzec.nama.om/en-us/Pages/tarifftype.aspx
[21] https://mzec.nama.om/en-us/Pages/solarpower.aspx
[22] Authority for Electricity Regulation (AER). Cost Reflective Tariff (CRT). Muscat Electricity Distribution Company (MEDC) 2018.
[23] R. Ahshan, R. Al-Abri, Al-Zakwani, N. Ambu-saidi, E. Hossain. Design and Economic Analysis of a Solar Photovoltaic System for a Campus Sports Complex. International Journal of Renewable Energy Research, 2020, 10(1): 67-78.
[24] M.C. A. García, J. L. Balenzategui. Estimation of photovoltaic module yearly temperature and performance based on Nominal Operation Cell Temperature calculations. Renewable Energy, 2004, 29: 1997-2010.
[25] G. M. Masters. Renewable and Efficient Electric Power Systems, Wiley, IEEE Press, 2013.
[26] M. Zeraatpisheh, R. Arababadi, M. S. Pour. Economic Analysis for Residential Solar PV Systems Based on Different Demand Charge Tariffs. Energies, 2018, 11: 3271
[27] IRENA, Renewable Energy Market Analysis, GCC 2019, International Renewable Energy Agency, Abu Dhabi, 2019.
[28] W. Li, et al. Cost comparison of AC and DC collector grid for integration of large-scale PV power plants. The Journal of Engineering, 2017, 2017(13): 795-800.

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ARTICLE

Cyber Security Awareness among Students and Faculty Members in a Sudanese College

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ABSTRACT

In the last few years, cyber security has been an essential prerequisite for almost every organization to handle the massive number of emerging cyber attacks worldwide. A critical factor in reducing the possibility of being exploited is cyber security awareness. Not only having the adequate knowledge but how to utilize this knowledge to prevent cyber attacks. In this paper we conducted a survey that focuses on three vital security parameters, which are trust, passwords and defensive attitude respectively. The survey mainly aimed at assessing cyber security knowledge of 200 students and 100 faculty members in a Sudanese college and how secure these participants think they are according to their current cyber behaviour. 56% of the participants are males and 44% are females. The results revealed that all participants were having fairly-low level of security awareness and their defensive attitude is considerably weak and doesn't protect them either individually or at institutional-level. Nevertheless, faculty member showed better cyber security knowledge and skills by 8% higher than students. This study can be used to develop training approaches that bridge the security gaps depicted by the respondents of the survey questions manipulated in this study.

1. Introduction

Cyber security, or information security, has become one of the major concerns of organizations, communities, and even individuals. Cyber-crime has increased steadily as technology advanced varying from robbery, identity theft, ransom, spying, and deception. That definitely confronts us with new challenges. Hence, it is mandatory for users to fully be aware of privacy and security risks and also have the sufficient awareness to protect themselves from cyber-attacks; as users represent the weakest part of the chain [1].

Cyber-attacks have been a trend in the few past years as companies and large organizations encountered catastrophic impact from such attacks including the loss of information assets, business disruption, equipment damage and revenue loss [2]. As it is expected that the number of cyber-attacks will grow in the near future, the notion that organizations need to be cyber resilient is becoming increasingly popular [3].

On almost a daily-basis cyber-attacks and exploits are conducted, exploiting miscellaneous vulnerabilities [4]. In contrast, defensive mechanisms are also being innovated to cope up with such a rapid pace to guarantee optimum levels of Information security; which is turning out to be a

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tough task as technology keeps advancing [5].

However, developing a defensive strategy needs a comprehensive study from different points of reference [6]. Firstly and foremost, it is essential to fully understand the available approaches for designing an optimum defensive strategy, then it is also mandatory to be fully aware of and even predict the strategies been adopted by attackers. Eventually, understanding that every technological approach in one way or another can be compromised by human behaviour [7]. In the other hand, attackers exploit vulnerabilities that most probably emerge from users not aware of cyber security practices; which in return facilitate the process of systems compromise for attackers [8].

Security awareness plays a pivotal role in our daily life nowadays, as users are expected to have, at least a clue about basic security risks and privacy policies, also their attitude towards how they can protect themselves from cyber-attacks is a critical factor when it comes to maintaining a robust cyber security approach [9,10].

In African countries, college students and faculty members are expected to have more computer-related technological literacy compared to other categories of the society, which also include having the adequate cyber security awareness to govern and utilize that literacy. Hence, carrying on a thorough study to validate this assumption is one of the major aims of this paper.

The rest of this paper is organized as follows:

Section II discusses some related work to the studies conducted on students regarding their cyber security awareness. The survey questions and the methodology followed in conducting the survey is highlighted in section III. Section IV and IIV preview the results and discussion correspondingly. Eventually, recommendations and conclusion are detailed in section V.

2. Literature Review

Several studies have been carried out in recent years to assess cyber security awareness level among college students and faculty members. Most of these studies aimed at conducting surveys encompassing elementary cyber security practices that form the first line of defence from trivial to massive cyber-attacks [11].

In [12], a study was conducted to understand how students of a Malaysian university were aware of the risks imposed by social networking sites, which revealed that about 33.3% of the students had been victims to some sort of social networking scams. Another study in the realm of social networking was conducted in [13] among 377 users of Facebook, Twitter and LinkedIn, where 41% showed a concern about online privacy and 44% were lacking the mechanisms of social networking privacy policy.

Senthilkumar et al. [14] performed an online survey for 500 Tamil Nadu college students regarding miscellaneous cyber security threats. The results revealed that 70% of the participants were fully aware of security practices to prevent virus attacks and they had been using up-to-date antivirus software. In the other hand, the remaining 30% of participants were reported to using antivirus software that is obsolete and 11% of them were not even using antivirus at all.

It might be observed that most of the studies managed to highlight that most participants don't have the sufficient awareness of cyber security practices and principles, also revealing much personal information that expose their privacy to considerable security risks without having them noticing. Moreover, the issue doesn't emerge from not having enough security awareness and knowledge but from applying that knowledge when it comes to cyber-related routine; which is tremendously challenging.

3. Methods

In order to assess cyber security awareness and practical applications among students and faculty member effectively, a survey was designed in a way that proactively consider three main factors: Level of knowledge, attitude and habits. The survey questions were designed to be brief and simplified to guarantee that participants don't get confused with advanced technological terms that might be disrupting, thus reduce the expected outcome but yet effective in assessing cyber security awareness and practices. There were 8 questions as follows:

(1) Do you use an up-to-date antivirus program?

(2) Do you access links sent to you by friends of a friend or even a friend without even observing the URL i.e. the link?

(3) If you are asked by an employee from the IT department at your college to provide him with your account password for any reason, would you do it?

(4) Have you ever used your phone number, birth date or even year of birth or a combination of your first name and birthday as your password?

(5) Does your password contain a combination of Alpha-numeric (A-Z or a-z or 0-9) and special characters (@, #, $ ...etc.)?

(6) Do you use the same password for all your accounts i.e. Email, Facebook account ...etc.?

(7) Would you use password unprotected Wi-Fi networks in public?

(8) Do you always sign-out from your personal or work accounts after you finish using it, even if you are using your own device?

The previously-mentioned survey questions evolved

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around three main scopes: Trust, passwords and defensive attitude. These scopes will be discussed below.

3.1 Trust

It is an undeniable fact that human-factors have been a topic of debate in Information security, as non-secure human behaviour can be easily exploited the less they lack awareness about Information security principles and practices [15]. Researches in the field of behavioural science and personality traits highlighted the matter of trust and how it exposes security breaches and they have been trying to design some methods to predict and analyse the behaviour of the attacker as well as the victim [16]. A consideration for gender psychology should also be maintained to understand how such factors affect the realm of cyber security [20]. Therefore, it was essential to consider trust as a main factor for keeping you safe or confront you to catastrophic impacts.

3.2 Passwords

In order to authenticate a user, both account identification and password are required. The process aims at indicating a specified resource to be fetched along with an authorization string associated with that identifier to guarantee an authorized access [17]. Many studies revealed that a lot of users tend to use easy-to-guess passwords, which almost incorporate part of their first name, the year of their birth or even their phone number, which is a common habit in Sudan. The issue lies in having the users using these passwords for multiple accounts, which might be disastrous if a hacker got a hand on the password [18]. Noting that account identifiers i.e. usernames didn't receive a considerable attention although they represent the first line of defence when it comes to security principles. This was essential to evaluate how our participants are ranking when it comes to passwords.

3.3 Defensive Attitude

The term attitude stands for (what you think) [19]. In cyber security, adopting a defensive attitude isn't always efficient because you might think you are safe and satisfied with the security practices that you follow; not knowing that you are putting yourself at the verge of being exploited as hackers are developing their strategies much rapidly than you can ever expect, which makes cyber security a major concern nowadays. Hence, it was essential to estimate how secure our participants think they are.

Taking into consideration the previously mentioned scopes, an overall of 300 participants were segmented into two categories; students and faculty members respectively. The two categories have been further categorized according to gender as shown in figure 1 below. Another factor that had been considered in this study is the average age of participants in the two categories, which was 22 years for students and 37.5 years for the faculty members.

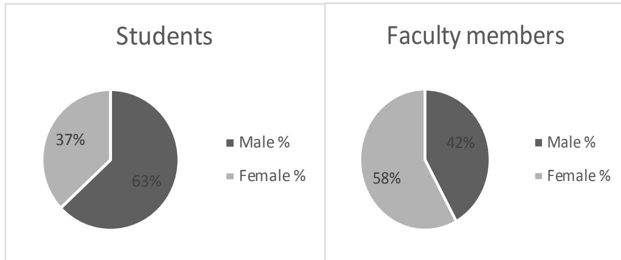

Figure 1. Pie charts that illustrate the percentage of participants from the two categories according to gender

The results of the survey will be discussed thoroughly in the next section.

4. Result

This section describes the results revealed from the survey conducted in this study, where the questions aimed at assessing the cyber security awareness among students and faculty members from specific perspectives, like how they might unconsciously forget to apply cyber security principles they know as being affected by their level of trust, how they manage their passwords and how secure they think.

Numerical Results

The response to the first question whether our participants use an antivirus program or not showed that a majority of 77.75% consent to use an up-to-date antivirus program while 22.25% didn't use or even know if they have an antivirus program installed on their devices or not. 78.5% of the students answered "Yes". On the other hand, 21.5% answered "No". Similarly, 77% of faculty members answered "Yes". While 23% answered "No", the majority were females 69.6% and a minority of 30.4% females.

The second question proactively measures the degree of trust in friends or acquaintance, where an overall of 74.75% answered "No". In contrast to 25.25% who answered "Yes" among both students and faculty members evenly. Again, the third question was intended to measure the level of trust in IT employees for both categories of participants. The results were as follows: 86% of students and 95% of faculty members agreed to provide IT employees with their personal identifier i.e. password. It was noticed that most of the responders who disagreed were hesitant at first and it was also obvious that they didn't answer confidently and took longer time than they did to

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answer other questions.

Then the questions ranging from four to six adopted the scope of how our participants manage to think regarding passwords, we were actually expecting them to use easy-to-remember yet easy-to-guess passwords that might expose their entire cyber experience to hazardous risks. Typically, as our fourth question highlighted, 97% of overall participants have used their phone number, birth date, year of birth or a combination of first name and birthday as their password, which makes it an easy task for hackers to guess their victim's credentials. However, three quarters of them managed to use a combination of Uppercase, lowercase, figures and special characters sometimes.

The most terrifying fact actually emerged from the response to question six, which indicated that 85% of our participants use the same password for multiple accounts. This "as a personal opinion" clearly depicts that the participants put their personal privacy in cyber security at risk as well as in a critical situation.

Question seven also retained a considerable agreement among both categories by 86% who might use an open public Wi-Fi. The rest 14% who disagreed were further asked about "why not?" and their answers were not related for security concerns as we expected but most of them reflected that they were satisfied with the cellular data connection either in their laptops via modems or via their phones.

Lastly, answers to question eight disclosed that a majority of 73.5% of students don't sign-out of their accounts but just close the page or window. Contradictorily, 81% of faculty members ensured that they got accustomed to sign-out of their accounts according to their work routine. Figure 2 below illustrates the level of security awareness among students and faculty members by evaluating the parameters discussed earlier in the preceding section.

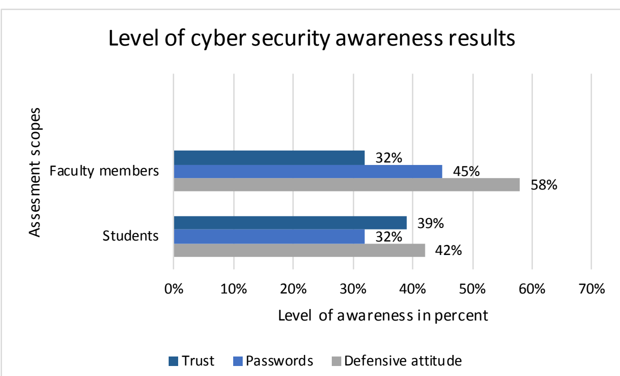

Figure 2. A bar chart that represents the level of cyber security awareness revealed by students and faculty members

5. Discussion

The levels of cyber security awareness for both categories of our study indicate that the mechanism of defensive attitude maintained by our participants is significantly unsecure and exposes them to cyber security risks. Most of the participants were aware of the importance of keeping themselves secure when it comes to information security but they were tremendously lacking the sufficient knowledge to keep them complying with the basic principles of such a challenging aspect. By considering figure 2, it is obvious that the average of cyber security awareness level is quite low. Yet faculty members exhibited better skill set and knowledge compared to students by 54% and 46% respectively as represented in figure 3 below.

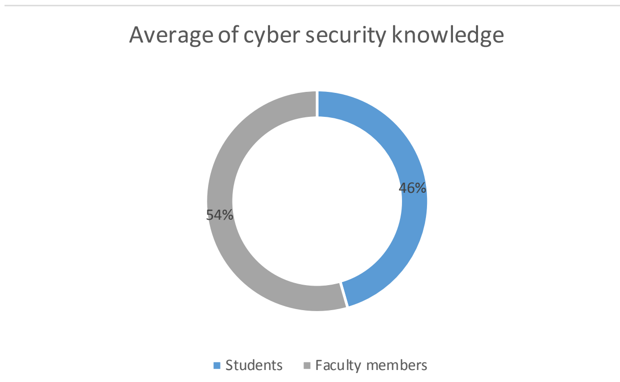

Figure 3. Average cyber security knowledge for students and faculty members

6. Conclusion

In this paper, a thorough study was conducted, aiming to assess the cyber security awareness among students and faculty members in a Sudanese college. As the technology is advancing rapidly, threats also increase; confronting organizations and educational facilities to miscellaneous attacks if cyber security knowledge and practices haven't been well considered. The results of the survey conducted were highlighting a severe lack of awareness when it comes to Information security. This might be reasonable because most of the participants are related to the medical field, which is "far away" from the realm of computer or information technology as they indicated but that's not reasonable if we consider that cyber security is turning out to be as serious as personal or even national security. Nevertheless, it is mandatory to amend our behaviour to cope up with such a high priority line of defence.

It is highly recommended to educate users i.e. students and faculty members about how to securely use their devices (including PCs, laptops, PDAs and mobile phones) safely from anywhere. One way to do this is by creating policies and regulations that govern the usage of information and devices in a simple way that can be easily understood. Another way is to include basic cyber security knowledge in the first year of the college or for early education levels such as primary or secondary school. It should also be extensible to include security at home, such as securing home Wi-Fi to securing IoT (Internet of Things) items; which are getting popular nowadays.

It is also essential to train users by implementing real-life scenarios to guarantee the effective practicing of the knowledge attained when confronted to a situation that might put their cyber security at the edge of exploitation. This paper can be considered to mainly focus on the points of weaknesses indicated by the individuals who had been questioned and designing an effective cyber security curriculum or at least, training sessions that fit all ages and consider the difference in students' specializations.

References

[1] Moallem, A. Cybersecurity Awareness Among Students and Faculty. Boca Raton, FL: CRC Press, 2019.

[2] Tareq Ahram, Waldemar Karwowski. Advances in Human Factors in Cybersecurity. Proceedings of the AHFE 2019 International Conference on Human Factors in Cybersecurity

[3] Aboul Ella Hassanien, Mohamed Elhoseny. Cybersecurity and Secure Information Systems_ Challenges and Solutions in Smart Environments, 2019.

[4] Cuthbertson A. Ransomware attacks rise 250 percent in 2017, Hitting U.S. Hardest. Newsweek, September 28, 2017.
www.newsweek.com/ransomware-attacks-rise-250-2017-us-wannacry-614034

[5] Yuri Diogenes, Erdal Ozkaya, Cybersecurity. Attack and Defense Strategies_ Infrastructure security with Red Team and Blue Team tactics, Packt Publishing, 2018.

[6] National Institute of Justice. 2018. The Fingerprint Sourcebook. NIJ.
https://www.ncjrs.gov/pdffiles1/nij/225320.pdf

[7] Adhikari, D. Exploring the differences between social and behavioral science. Behavioral Development Bulletin, 2016, 21(2): 128-135.

[8] Crossler, R.E., Bélanger, F., Ormond, D. The quest for complete security: an empirical analysis of users' multi-layered protection from security threats. Inf. Syst. Front. 2017, 1-15.

[9] Cuthbertson A. Ransomware attacks rise 250 percent in 2017, Hitting U.S. Hardest. Newsweek, September 28, 2017.
www.newsweek.com/ransomware-attacks-rise-250-2017-us-wannacry-614034

[10] Young, H., van Vliet, T., van de Ven, J., Jol, S., Broekman, C.: Understanding human factors in cyber security as a dynamic system. In: International Conference on Applied Human Factors and Ergonomics. Springer, Cham, 2018: 244-254.

[11] Farzan A. College students are not as worried as they should be about the threat of identity theft. Business Insider, 2015.
www.businessinsider.com/students-identity-theft-2015-6

[12] Grainne H. et al. Factors for social networking site scam victimization among Malaysian students. Cyberpsychology, Behavior, and Social Networking, 2017.
DOI: 10.1089/cyber.2016.0714

[13] Hossain A., Zhang W. Privacy and security concern of online social networks from user perspective. International Conference on Information Systems Security and Privacy (ICISSP), Angers, 2015: 246-253

[14] Senthilkumar K., Easwaramoorthy S. A survey on cyber security awareness among college students in Tamil Nadu. IOP Conference Series: Materials Science and Engineering, Volume 263, Computation and Information Technology, Tamil Nadu, 2017: 1-10.

[15] Wisniewska, M., Wisniewski, Z. The relationship between knowledge security and the propagation of innovation. Adv. Intell. Syst. Comput. 2019, 783: 176-184.

[16] Winston-Proctor, C. E. Toward a model for teaching and learning qualitative inquiry within a core content undergraduate psychology course: Personality psychology as a natural opportunity. Qualitative Psychology, 2018, 5(2): 243-262.

[17] Brumen, B., Taneski, V. Moore's curse on textual passwords. In: 2015 28th International Convention on Information and Communication Technology, Electronics and Microelectronics (MIPRO), 2015.
https://doi.org/10.1109/MIPRO.2015.7160486

[18] Stainbrook, M., Caporusso, N.: Convenience or strength? Aiding optimal strategies in password generation. In: International Conference on Applied Human Factors and Ergonomics. Springer, Cham, 2018: 23-32.
https://doi.org/10.1007/978-3-319-94782-2_3

[19] Kruger H., Kearney W. A prototype for assessing information security awareness. Computers & Security, 2006, 25(4): 289-296

[20] Wayne Patterson, Cynthia E. Winston - Proctor - Behavioral Cybersecurity. Applications of Personality Psychology and Computer Science. Taylor & Francis. CRC, 2019.

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