DEVELOPMENT OF A STAND-ALONE SOLAR POWERED BUS STOP

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ABSTRACT

This paper presents the development of a stand-alone solar photovoltaic (PV) system for bus stop at Universiti Teknikal Malaysia Melaka, Malaysia. The design intent for the bus stop was to provide lighting and information to the bus stop users using reliable renewable energy system as well as to promote green technology awareness to the university residences. The stand-alone PV system was designed to power two units of CFL lamps and an LED display unit installed at the bus stop. Five units of polycrystalline photovoltaic modules with 110W rating each and four deep cycle battery units were utilized to provide three days of autonomy period for system operation. A part from that, 15 degree of tilt angle was selected for PV module placement to provide optimum energy generation as well as self cleaning for the modules. After the bus stop structure construction, the PV system was installed and commissioned. Final results from the commissioning process showed that the system is able to operate successfully as per design requirement.

KEYWORDS: *Solar photovoltaic, Bus stop, Stand-alone system*

1.0 INTRODUCTION

Photovoltaic or PV is currently one of the most attractive options for renewable energy resources in the world. Malaysia which is blessed with yearly average solar irradiance of 1400 to 1900 kWh/m^2 is considered to be in a very advantageous position to harness the unlimited energy towards PV applications to cater current domestic energy demand (Malaysian PV Handbook, 2009). The technology offers free and renewable energy, no emission effects during energy production, help to reduce dependency to conventional power supply, as well as easy to install and maintain due to its modular characteristics (Chow, 2010).

Up to date, solar photovoltaic (PV) system application is divided into two distinctive categories, which are grid-connected system and stand-alone or off-grid system. The grid connected PV system operates by linking the solar PV with the utility-grid connection, where as the stand alone PV system operates without connection to the utility grid and utilize a battery system to store the excess energy generated by the solar PV as well as supplying the needed energy when no power from the sun is available. Both system are widely applied especially in Malaysia, however the stand-alone system offer notable

In this project, an innovative design of bus stops is proposed where the infrastructure is to be equips with lamps and electrical signboard powered by solar PV energy system. The new system is aimed to provide higher level human comfort as well as information to user, and the prototype is targeted to be applied in Main Kampus, Universiti Teknikal Malaysia Melaka. Currently, bus stops in UTeM is designed without any equipment to provide proper notice board and LED display to give better information for the public. This paper described the overall design and development process for the UTeM solar powered bus stop such as PV system sizing, structure design and development as well as PV system installation and commissioning.

2.0 METHODOLOGY

The overall research methodology implement in this project is shown in Fgure 1 below.

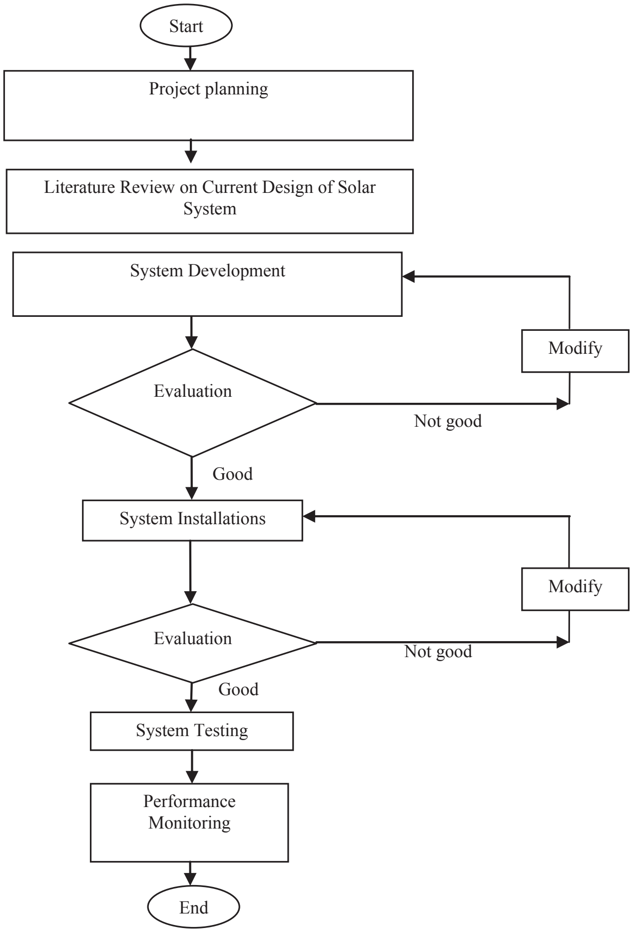

FIGURE 1 Overall Research Flow Chart

Among the important stage in this project was the system development where the sizing of the PV standalone system is conducted. In order to attain an optimum design for the system, several sizing criteria such as location selection, design specification, determination of PV modules and battery capacity etc. were carefully calculated based on MS1837:2005 PV standard requirements (Malaysian Standard, 2005). The structure was later designed to accommodate the system sizing results using Solidworks CAD software. System testing and commissioning were performed in the final stage of the project to ensure that the PV system able to operate as per requirement.

3.0 SYSTEM SIZING

3.1 Selection of Bus Stop Location

The first approach in designing the UTeM solar bus stop was to choose the suitable location for the structure. This is very crucial in order to ensure that the solar modules installed later on will have exposed to adequate sunray throughout the entire day for maximum power generation. The surrounding of the bus stop location was also ensured to be clear from shading sources such as tress and nearby structure especially to the solar modules. The bus stop must also be easily accessible to the users to serve its main function. The proposed location of the UTeM solar bus stop is shown in Figure 2 below.

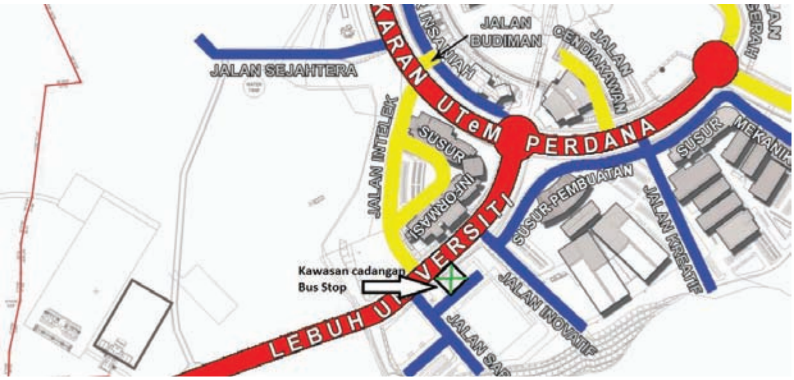

FIGURE 2 UTeM Solar Bus Stop Location

3.2 Load Determination

The details of the electrical appliances designed for the bus stop and its power rating is shown in Table 1 below. Based on Table 1, the majority of the loads selected operated on AC current. This is mainly because of low cost of acquiring the component compared to DC current components. A part from that, the system load is also divided into two cases which are with and without spare loads. The spare loads are incorporated into the design to cater for unexpected higher power usage in the future. The total load per hours in the case of without spare load is 953 Watt-hours daily and in the case of spare loads is 1269 Watt-hours daily.

TABLE 1 Load profile for UTeM solar bus stop in a day

No	Load Detail	Type	Quantity	Power/Unit (W)	Operating Time	Operating hour/Day	Total Power (Wh)
1	CFL Lamp	AC	2	18	7pm – 1am	6	216
2	LED Display	AC	1	49	8am – 10pm	14	686
3	Internal System	DC & AC	1	8.5	-	6	51

4	*13A socket	AC	1	100	-	1	100
5	*Spare loads	AC	2	18	-	6	216

3.3 System Specification and Tilt Angle

Several parameters have been determined for the design specification of the solar bus stop. First and foremost, the new UTeM solar bus stop is set to operate as a standalone system, where the power source is generated through PV modules only. The system is also set to be operated using 12V system voltage and must be able to operate up to 3 days of autonomy (in the case where zero sunlight occurred). The estimated achievable maximum solar radiation per day for the system is set to 3 peak sun hours and because the bus stop is a standalone photovoltaic system, the maximum depth of discharge for the battery used is the system is set to 80% capacity. The solar module is set to be placed on top of the bus stop roof to avoid any shading and to optimize the bus stop area. Hence, another important parameter that was determined was the tilt angle for the solar module installation. The location for the bus stop is roughly at the latitude 2°18'51.61"N and longitude 102°19'8.17"E, where, optimum tilt angle for the solar module is from 2° to 3° facing south. However, it is recommended that for sites at latitudes between 15°S and 15°N, a tilt angle of 15° is used. Hence, the tilt angle selected for the bus stop design is 15° to enable optimum energy generation as well as self cleaning for the modules. Based on solar irradiation data for Malaysia, the approximate average solar irradiance for the given latitude is 1400 W/m^2 (Sulaiman et al., 2008).

3.4 Battery and Module Sizing

Based on load data in Table 1 and design specifications, the sizing of the battery unit and the solar PV modules were performed. The determination for the number of batteries and PV modules were carefully conducted to ensure optimum sizing of the system can be achieved, which will benefits in lowering down the overall system cost as well as ensuring the system is able to operate efficiently. The sizing approach for standalone system is more delicate because the system operates solely on solar energy and energy from the batteries, compared with grid connected system. The battery must be able to supply the required power for minimum 3 days autonomy while the PV modules must be able to supply the power during sunlight as well as charging the battery to its maximum capacity continuously. Table 2 below shows the final result for the battery and PV module sizing.

TABLE 1 Sizing for Battery and PV Modules

Sizing Details		Value
A. Battery		
i.	Amp-hour required excluding spare load (Ah)	297.8
ii.	Amp-hour required including spare load (Ah)	396.6
iii.	No of battery need	4
B. PV Module		
i.	Maximum power, P_m (W)	110
ii.	Maximum voltage, V_m (V)	17.2
iii.	Maximum current, I_m (A)	6.4
iv.	Short-circuit voltage, V_{oc} (V)	21.7
v.	Short-circuit current, I_{sc} (A)	6.9
vi	Total module required excluding spare loads	4
vii.	Total module required including spare loads	5
viii.	Array configuration	5 x 1

3.5 Balance-of-system (BOS) Sizing

The final procedure for the sizing is to determine the specification for charge controller and inverter. The charge controller is used to regulate the power from the PV modules to the loads and vice versa efficiently. The inverter in the other hand is selected to convert the DC voltage produced from the PV modules to AC voltage needed for the load operations (CFL lamps, LED display etc.). The results of the balance of system sizing are shown in Table 3 below.

TABLE 3 Balance-of-system (BOS) for UTeM Solar Bus Stop

BOS Sizing Details		Value
A. Charge Controller		
i.	System voltage : minimum/maximum (V)	12/24
ii.	Total rated solar current (A)	18.5
iii.	Total maximum array current (A)	26.5
iv.	Total rated load current (A)	7.8
v.	Total maximum load current (A)	19.2
B. Inverter		
i.	AC system voltage (V)	240
ii.	AC system frequency (Hz)	50
iii.	Power factor (cos(pi))	0.85
iv.	Rated VA based on excluding spare loads	110
v.	Rated VA based on including spare loads	270

A part from that, another important parameter for the BOS is the appropriate selection of cable size to minimize the power transmission lost in the cables. Due to the small amount of energy generated by the PV modules, thus the sizing process in this project was also focused to reduce any losses that may be created in the system which can deteriorate the system performance. The diameter of cable size selected is 4mm for running from the charge controller to the loads as well as from the batteries to the charge controller and 6mm cable diameter for cable designed from the PV modules to the charge controller. The selected cable sizes for the whole system were carefully calculated to permit maximum cabling losses of 4% based on requirement stated in the Malaysian Standard (Malaysian Standard, 2005).

3.6 Results of System Sizing

Based on the system sizing, the appropriate components for the UTeM solar bus stop system were selected. The design specific yield of the system is 1037.1 kWh/kWp. The installation quality of the designed bus stop measured in term of performance ratio was found to be approximately 74% which satisfy the MS1837:2005 PV standard requirements (Malaysian Standard, 2005). A timer was also incorporated in the system to control precisely the operation hours of the loads in the system. Table 4 and Figure 3 below show the description of the selected equipments for the standalone PV system and the system overall schematic diagram.

TABLE 4 Equipments for UTeM solar bus stop

No	Item	Quantity	Desciptions
1	Solar Module	5	110 W, 12V, Polycrystalline. Brand: SolarTif
2	Battery	4	100 Ah, 12V, JXH100-12 Valve Regulated Lead Acid. Brand: MPower
3	Charge Controller	1	Model PL40, 12-48V, 30A. Brand: Phocos
4	Inverter	1	Standalone Sinewave Inverter, Model Picollo.Brand: ASP

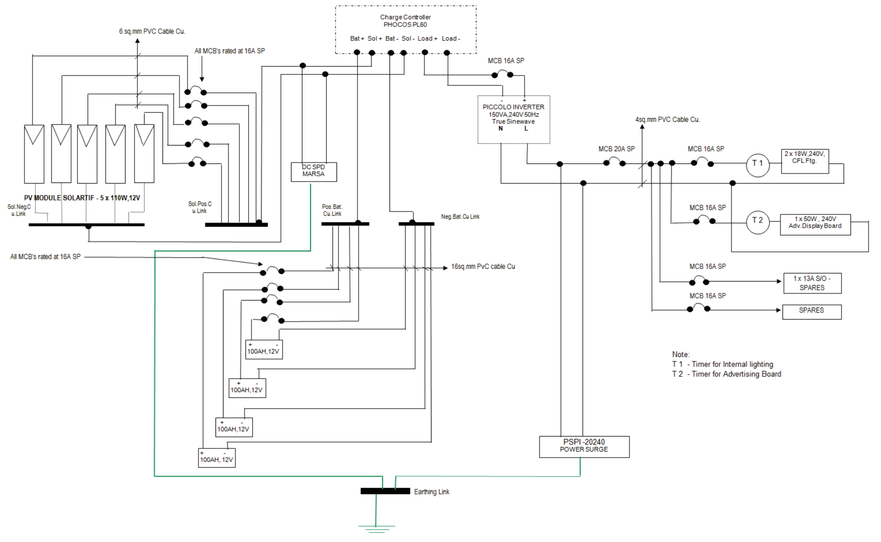

FIGURE 3 Schematic Diagram of the UTeM Solar Bus Stop

4.0 BUS STOP DESIGN AND CONSTRUCTION

The design intent is for the bus stop to provide lighting and visual display to the users of the bus stop. A part from that, the bus stop structure must also be able to accommodate the solar modules as well as the rest of the balance of system components. Acknowledging the above requirements, a design for the UTeM bus stop was proposed and shown in Figure 4 below.

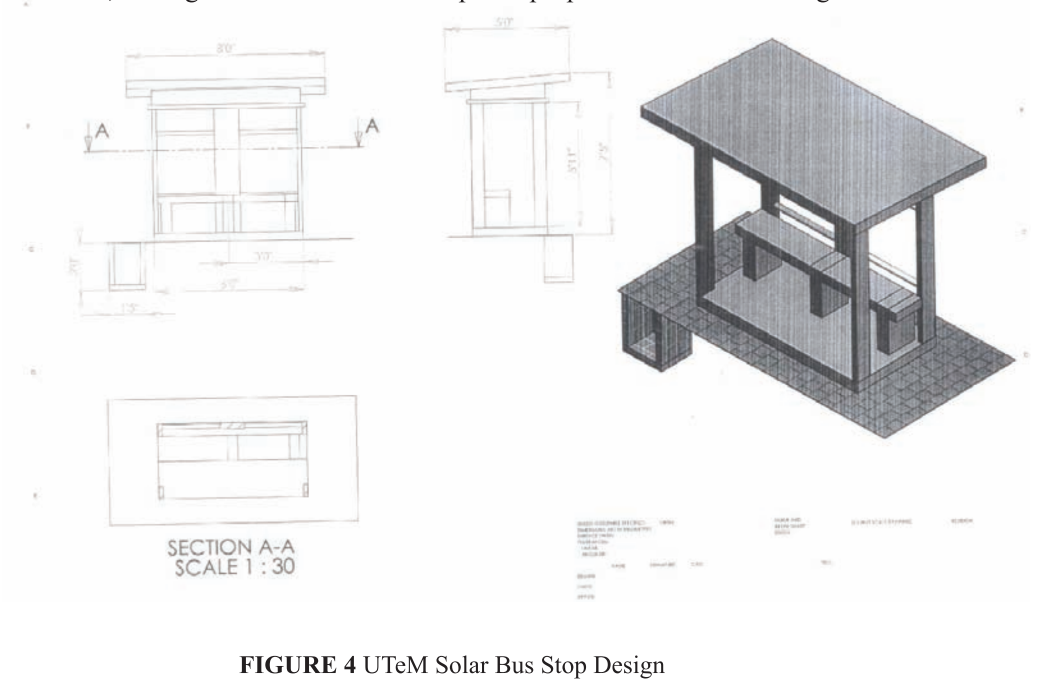

FIGURE 4 UTeM Solar Bus Stop Design

The UTeM bus stop structure encompassed several features. The roof of the structure is tilted at 15 degree from horizontal plane to enable tilt angle of 15 degree for the module installation. The bus stop foundation is needed to be flat to ensure the tilt angle for the modules can be achieved. The roof structure also houses the CFL lamps and LED display unit. Due to the location of the LED display unit where it is placed on the front of the bus stop roof facing the main road, the display is required to be fabricated based on IP65 casing requirement for ensuring reliable outdoor performance. The overall structure of the bus stop will be made from concrete as well as for the base of the bus stop. The balance-of-system components are located separately in a special housing behind the bus stop structure for ease of maintenance and security control. Figure 5 below show the UTeM bus stop in the end of the construction process.

FIGURE 5 UTeM Bus Stop after Construction

5.0 SYSTEM INSTALLATION AND COMMISSIONING

After the bus stop structure was constructed, the stand-alone PV system was later installed at the location. Simple L-shape brackets were first placed on top of the structure roof acting as the mounting points for the PV modules. Five units of PV modules were installed in 5x1 array configuration as per sizing requirement at 15 degree tilt angle. Later, the CFL lights and LED display unit were installed on the bus stop. The batteries and balance-of-system components were installed separately on a special housing behind the bus stop. Wires connecting the modules, loads and the rest of the PV system are secured inside conduits to ensure safety to the users as well as to protect from surrounding effect such as rain water that may cause it to deteriorate prematurely. The wires connecting the modules and the balance-of-system housing is also burried in ground for safety purposes. The installed PV system on the bus stop and the PV balance of system are shown in Figure 6 and Figure 7 below.

FIGURE 6 UTeM Stop with Stand-alone PV System

FIGURE 7 Housing for Batteries and Balance-of-system Components

6.0 CONCLUSION

In conclusion, the standalone solar PV system for UTeM green bus stop was successfully developed in this project. The solar PV system comprised of five polycrystalline modules in 5x1 array configuration and four deep cycle batteries which give power to two units of CFL lamps and a LED display unit. The bus stop structure was design and constructed to accommodate the module tilt angle of 15 degree. Results from the testing and commissioning process performed show that the solar PV system was able to perform as per design requirement. The solar powered bus stop developed in this project was proven not only to perform as conventional bus stop, but also able to provide human comfort and information to the users as well as promoting green technology within the university and its residence.

7.0 ACKNOWLEDGEMENT

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