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Analytical Modelling of Premises-Specific Solar-Energy Estimation

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Abstract: ***Solar energy is great potential for future energy due affordability of solar related panels and equipment. Solar-Energy Microgrid for serving DC and AC loads of areas under consideration. Microgrid is a new concept for making safe, clean, and renewable solar available for use. Most of the countries have developed it solar farm in order to harvest the energy and make it useable for daily use. This energy can be used either for premises-specific loads and also distributed to other regions through the national grid through what is called Distributed Generation (DG). Estimating solar energy potential estimation of premises under target is obviously an exercise that may prove in the design of such DG microgrids. This paper presents two analytical modelling approaches for estimating the solar energy potential of a given geographical location. The two approaches are explored for estimation two very closely related amount of solar energy in kWh for eleven hours of time of a day using Heliocentris Hybrid Energy Lab-System data. The approaches may find utility in the pursuits of the renewable energy estimation needed for designing PV-solar microgrid. The mismatch of 6.31% energy estimation between the two approaches may be due to parametric complaint inaccuracy instead of the approaches employed.***

Keyword: ***microgrid, distributed generation, renewable energy***

I. INTRODUCTION

Solar energy is one of the sources of renewable energy that has been used widely. The unlimited source of solar available makes it one of the largest energy harvests next to wind energy potential. Using renewable energy leads to reduction in losses incurred due to transmission and distribution systems. The intermittent nature of renewable energy makes it highly unreliable and research is underway to make it as a source providing consistent power.

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The sun shines brightly for nearly 365 days per year with the penetration of light through space reaching the earth's surface for almost 10 to 12 hours at one location in most parts of Malaysia which makes it as one of the potential of harvesting energy sources for domestic supply sources. The energy so received may be even made to be distributed to the nation through the direct current (DC) standalone microgrid system or be fed by tying it to the national grid [2].

DC microgrid system is a system that generate energy supply at one spot and the energy is used domestically for everyday use. The advantage of having DC microgrid is to reduce the energy loss from the long distance transmission line normally raised and setup in the conventional AC transmission system. Such generation of renewable energy is genuinely referred to as Distributed Generation, as it provides for the variable load from sources which are random in nature [2-5]. The research focus here at how to model a variable load target area before proposing to install DC microgrid from solar sources of generation. The DC microgrid installed at one spot will be directly, efficient and reliable to that location [6]. This paper present analytical modelling and mathematical approach to the solar energy harvested using the laboratory testbed installed in Advanced Technology Training Centre (ADTEC) in Kg Payoh, Kemaman Terengganu, Malaysia. The contribution of the work consists of using piece-wise linear approach used in analytical modelling of the generation potential and then suggesting a relevant integrated microgrid structure for the required power generation, estimating ultimately designing the target standalone microgrid system for the target area.

II. METHODOLOGY

a) Installation of Energy Lab

ADTEC Kemaman is located in Kg Payoh, Kemaman, Terengganu on area of the size of 100 acres. It is one of the training centres in Malaysia, built up for the Technical and Vocational Education and Training (TVET) in order to train students to become technologists. The energy lab has been installed in one of the buildings for the students to study and learn skills regarding the installation of solar panels and related electronic equipment for generation of solar energy. The energy solar panel has capacity of 25.3V and the current I_{SC} to be rated at 8.52A. The panels are fixed mounted with one of the panels is facing the direction of 45 degree to the West and tilt 85 degree to the sky and another panel is facing 45 degree to the East and tilt 45 degree to the sky.

The hybrid energy lab system is consist of equipment for the Renewable Energy System (RES) which the source are from solar, wind, fuel cell (hydrogen) and energy storage system.

b) Distributed Generation (DG)

Distributed Generation (DG) is said to be the installation within the network to reduce the need of transmission and high voltage distribution system. Microgrid is a concept connecting large number of distributed power generation sources, particularly renewable energy sources of solar, wind, biomass, oceanic tidal, and microturbine hydroelectric together for serving local and national load. In the case of local load, it stays most of the time as DC, while in the case of serving national, the microgrid is tied for the integration to the national grid supply at the low voltage distribution level. This trend of technology is on the rise due to the renewable energy products affordability and evolving living priorities due to environmental group's pressure for pollutants reduction [7][8].

Fig. 1. Location of Photovoltaic (PV) Solars Panels Installation

The DG structures have got its merits of the assets on spot utilization, enhanced power quality by being available, and better system reliability by avoiding mixing with the systems, flexibility by being added/removed easily, and capacity using modular structures in integrated fashion. Such structures give rise to what are started known by the names of micro-grids. Microgrids have the preferential benefits of being islanded easily in the case of accidental or transitional conditions on the main grid system. Also, conceptually microgrids are better modularly structured for inter-connectivity before getting integrated with the system as shown in Figure 2. In the islanded mode, the system needs to control the sharing of load with different units and to balance the power in the microgrid. To achieve arriving at such aims is done by using the centralized or decentralized power management [13]–[17]. The centralized method of control strategy will rely on the communication between sources and the loads which reduce the reliability of the system [18], something has to be addressed.

Decentralized control method through using a chain of converters however requires local measurements and also the non-crucial communication can be used in order to achieve other aims such as restoring voltage and frequency deviations. This work addresses the features any future renewable energy converter chains are expected to be equipped with such that it an emergency situation they adapt to performing in roles supporting the on-going system problems of voltage compensation instead of islanded altogether.

The control of power flow in the DG embedded system is needed in order to turn ON and OFF the power converters in a way of effectively targeting the aims priory mentioned aims. This strategy is needed so that the DC bus as shown in Figure 3 can be maintained at a certain level so whenever the load demand is needed in serving the local load leading us to control the energy power from either the DG such as solar, wind, fuel cell or wind turbine will be directed to the local load. The excessive power flow from the DG will then directed to the energy storage system (ESS) in order to charge the battery packs to be at the maximum power rating. Also, whenever the power is needed to be supplied to the national grid, it can be converted to AC when power is required to be sent along the AC bus to the national grid [15].

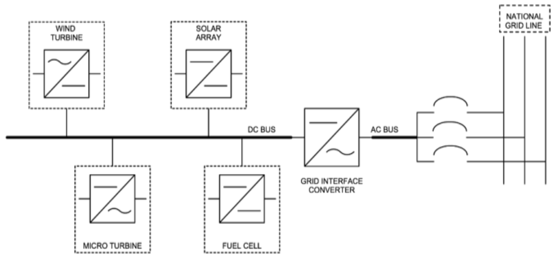

Fig. 2. Distributed Generation for DC Microgrid

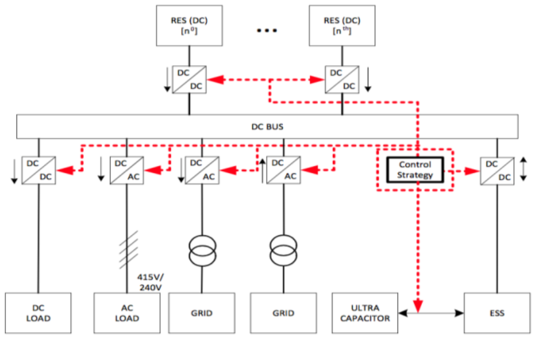

Fig. 3. Control Strategy for the Power Flow

As for the DG, the intermittent nature of power is the challenge issue for renewable energy sources. For example the changes of climate from bright sunny days to cloudy and also from day to night for the solar will affect the power generation and as well as the wind turbine will depend on the speed of change of wind. Therefore, during the intermittent, in order to maintain the DC bus at a certain level, the control will then send the power from the ESS back to the DC bus and so that the interruption of the power loss is recovered.

III. RESULT AND DISCUSSION

a) Modelling of PV- Power Capacity

Solar power generation depends on the temperature as well as irradiation of solar energy alongside solar panels orientation of the target area of ADTEC Kemaman, one can estimate the solar potential of area under consideration (AUC) using the technique of [16].

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In this work is used data of Heliocentris Hybrid Energy Lab-System source as shown in Figure 4, which is linearly approximated to what is as shown in Figure 5.

Fig. 4. Power generation for the period of 07.00am to 06.00pm

Figure 4 shows the power that has been generated from the PV for the period of eleven hours starting from 07.00 am to 06.00pm.

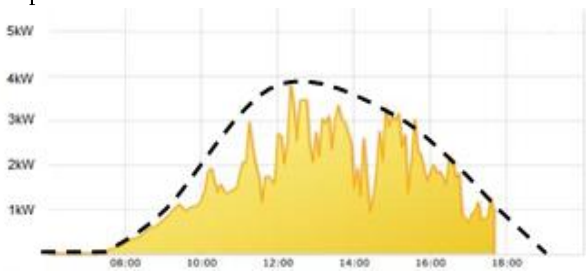

Fig. 5. PV-power normalised approximated to dotted line

From Figure 5, the maximum power generated reached at 12:00 noon. The power generated increased gradually from 08.00am and reach maximum power generated at 12.00 noon then decrease gradually until 06.00——————————————————————————————pm.

b) Analytical Estimation of Energy Generation

Figure 6 shows the plot that is segmented into a few separation time slots in order to find the area under the plot for each segment and to sum up each areas to find the total energy generated for one day. Such mathematical calculation is produced as the following the mathematical calculation area and calculated as follows:

Area (a) = $\frac{1}{2}\ x\ 2.33\ x\ 1 = 1.17kWh$

Area (b) = $\frac{1}{2}\ x\ 2\ x\ 1.5 = 1.5kWh$

Area (c) = $2\ x\ 1.5 = 3kWh$

Area (d) = $2\ x\ 3.8 = 7.6kWh$

Area (e) = $2\ x\ 3.2 = 6.4\ kWh$

Area (f) = $\frac{1}{2}\ x\ 2\ x\ 2.5 = 2.5kWh$

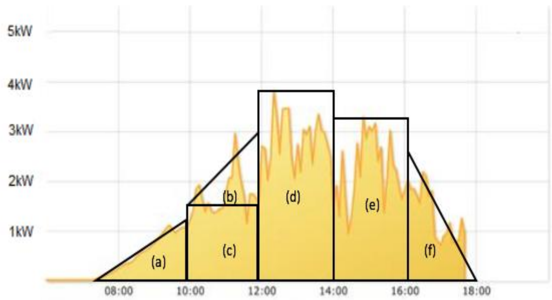

Fig. 6. Segmentation for calculation area

Resulting thus into total area, Total $_{(a)\ (f)}$= 1 + 1.5 + 3 +7.6 + 6.4 + 2.5 = 22.17 kWh

The above total power can be worked by the integration mathematical calculation after having represented the PV-solar plot of Figure 4 by linear segments as shown in Figure 7. Every segmental line can be expressed by a slope 'm' and y-intercept 'c' of linear equation of $y = mx + c$, using which we obtain what is given as under:

$$f(a) = 0.57x - 4.26$$
$$f(b) = 0.64x - 5.14$$
$$f(c) = -0.53x + 10.47$$
$$f(d) = 0.9x - 10.30$$
$$f(e) = -0.3x + 7.70$$
$$f(f) = -0.8x + 15.40$$

The area under the lines (a)-to-(f) are estimated by using ordinary integration formulas will be used and the integral of the equations shall be sum up in order to get the total energy generated in kWh.

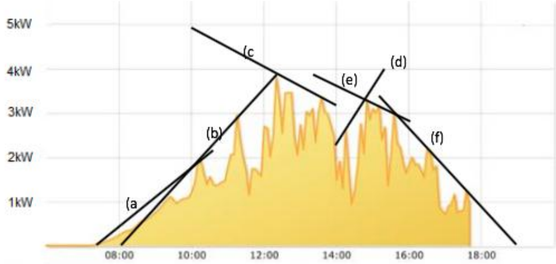

Fig. 7. Integration Calculation to calculate area under graph

For example, in the case of area under the function f(a), the integration follows as:

$$f(a) = \int_{7.5}^{10.67} 0.57x - 4.26\ \ dx$$
$$= 29.8\ kWh$$

And the rest of the function give the value of $f(b) = 460.8\ kWh$, $f(c) = 420\ kWh$, $f(d) = 171.2\ kWh$, $f(e) = 310kWh$ and $f(f) = 233.55kWh$

The techniques of working out the total energy generated from PV-solar at have got a close resemblance with mismatch attributed possibly to the difference in estimating the slopes, y-intercepts or limits of integration. The total energy generated in the latter case is 23.57kWh. From both of the results, certain considerations have to be taken into account such that the area is also included the one that the power generation has loss power. As can be seen from the Figure 4, the power generated is considered intermittent that like at 1020am to 1100am the power is loss. This situation may be due to the cloudy weather that block the PV and cause the power loss. In order to overcome this problem, it is suggested that the use of ESS will recover the power loss. However, one consideration shall be taken like the power loss due to voltage drop from the ESS's switching to the DC bus need to be overcome by using the ultra-capacitor that need to be done further.

IV. CONCLUSION

From the results and discussion, the power generated from the PV will be a benefit to the community where the electrical power can be harvested for the domestic daily use and while the PV area is large this will make the one local spot for the microgrid and connected to the nearest village. In the islanded mode, the PV-farm will be adequate to supply the electrical energy to one village, and the surplus may be connected to the national grid for meeting the load demand of a nearby locality. The two analytical approaches used for analysing data for Heliocentris Hybrid Energy Lab-System source have produced amounts of energy over the same duration two amounts differing by 6.3 % inaccuracy could be attributed to parametric values, which could not be a measuring stick to decide on the authenticity of the approaches. Furthermore, the results of this work will be used in a subsequent venture for the power flow for addressing the microgrid supply availability concern.

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