On the Dynamics of Floating Solar Power Plant: Opportunity for Sustainable Energy Generations

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Abstract- Continuous evolvement and development of various types of solar power plant show that there is a huge demand in the solar energy for the present as well as the future. Moving along with the trend, grid-connected floating solar PV power plant (GFPV) act as a favorable and cost-effective alternative to the land or roof based power plants. The inclination towards the go green with renewable energy adaption makes the GFPV makes the highest potential verticals. We are going to analyze the possibilities and aspects of GFPV over the lake present in our campus. In this analysis, need to identify the possibilities to utilize the available lake into the sustainable lake. We will be in the position to calculate the efficiency of modules when the modules are exposed to natural air and water cooling after implementing the FPV on a full scale as a pilot project. This proposed analysis can also involve in self-purification of the lake.

Keywords: GFPV; FPV; design parameters; HDPE;

1. Introduction

In recent years growth for renewable energy is massive. Solar energy is the best suitable alternative energy resources in the alternatives. There are a lot of applications are available using solar energy but most prominently solar photo voltaic is adapted. In recent years, the demand for the utilization of available barren ground for ground mounted and roof mounted system is getting limited. Because of this particular constraints, people started to migrate to the floating solar power plant (FPV). Even FPV is gaining more attraction on the dams and reservoirs. [1] TNB puts to test first pilot FPV in 2015 of 100KWp in Sg Labu water treatment plant in Sepang, Selangor.

2. Literature survey

Following article [2] discussed about various types of solar PV power plants and shows that lot of advantages of FPV like, increased efficiency, reduced evaporation of water, improvisation of water quality, less dust effect, land saving, even with respect to the advantages following disadvantages is there which does not show the adverse effect like increased corrosion, less photosynthesis process, reduced humidity, and thermal drift can cause downgrade the efficiency of the plant, aquatic habitats may get affected. In spite of the fewer drawbacks, it is understood countries like Japan, California, Italy Spain and France are the major players with installation capacities in the range of Megawatts. As per their findings, it is assumed that the payback period will be in 5 years considering the cost occurs for 1 MW plant. It is also analyzed various possibilities of commercial and research-based erecting systems.

There is a possibility of exploit water as energy vector [3], these works represent that FPV need not be over the surface of the water but as well as submerged in water as per the experimental approach of submerging in deep water and shallow water which shown in fig 1. Pure water is acting as a high pass filter with allowing the high bandwidth of 350nm to 550nm in the visible region where the solar cells work as normal. Due to the combination of ambient temperature and irradiance, energy yield can be greater or smaller which totally depends on the depth of the water. Tracking also possible by rotating the entire floating platform along the vertical axis reduces the cost required to provide tracking for roof or ground top models by providing with confining structure, rope system, submerged structure, bow thrusters. All the tracking unit consists of electronic guidance system (EGS) to follow the sun path, depends on the type the system rotates as per the EGS Concept

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of East-West racking also possible in certain structures which were proposed in Korea. In 2012 Hydrelio developed (High-Density Poly Ethylene) HDPE was very robust and easy to erect the structure with basic modular rafts. Cleaning of FPV is far easy and efficient when compared to other types. The proposed water veil cooling (WVC), because of the refractive index of 1.33 proves to be suitable for cooling the modules by reducing the reflection effects of radiation. This process gives a gain of 2% when the radiation is perpendicular to the module and reaches 6% when the tilt angle is less than 30^{o}. The overall drop in temperature of 17^{o} is proved in their work by switching on WVC with negligible losses in the radiation which is shown in fig 2. They also proposed sprinkler cooling system alternate to WVC but still, we need to face the problem water jet transparency which is shown in fig 3.

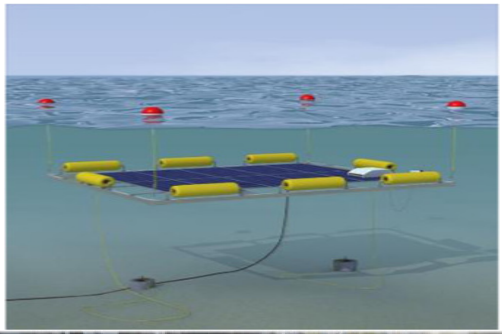

Fig. 1. Submerged SP2 plant with sinking system.

Fig. 2. Picture of the experimental WVC installed on an FPV plant in Pisa (Italy)

Fig. 3. Sprinkler cooling system.

From their experience of the two plants at Pisa and Suvereto with and without tracking is fitted with cooling a tracking is measured and found that the rise in 30 % overall energy production. Using of flat reflectors is partially helped in reduction of KWhr price. Using of raft pipes as storage mechanisms for compressed air reservoir for an isothermal process leads to another area of research.

Another part of work insists integration of FPV and water network gives more yield for irrigation as well as power generation [4] shown in fig 4 and fig 5. Various analysis has carried out with proof –of –concept prototype which leads them to cover entire reservoir with 750 pontoons on the area of 4490 m^2 with 1458 PV panels generating 300KWp generating 425,000 kWh / year with the performance ratio of 78.22. total 2048.5-ton CO_2 emissions were reduced. Therefore by covering the reservoirs the water from the reservoir is free from photosynthesis and weed development. The water becomes purely useful for irrigation.

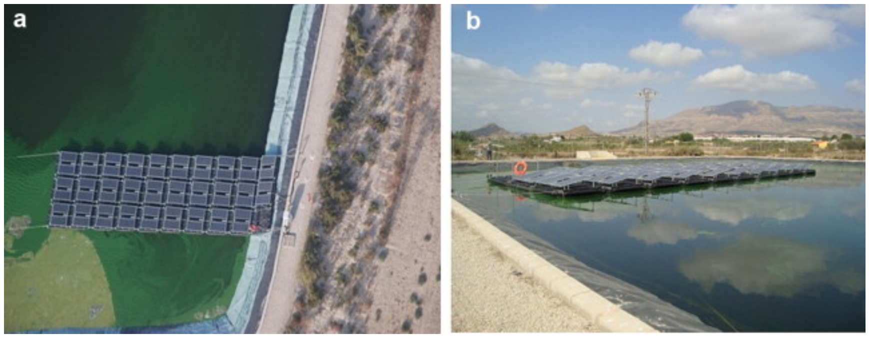

Fig. 4. FPCS prototype: a) Aerial view; b) Side view.

Fig. 5. The reservoir completely covered by PV panels.

FPV on wastewater basin is explored in Australia [5] with the main goal of reduction of water evaporation by providing shading to the water basin to avoid incidence solar radiation and effect of wind over the surface of the basin. In this work, the authors have explored the options of integrating FPVs with the wastewater treatment basins for the advantage of environment and energy production. From their work it is understood roughly 15,000 – 25,000 cubic meter of water can be saved for each 1 MWp which shows the importance of this FPV in dry areas with water scarcity.

By understanding the above literature survey it clearly shows the various advantages as follows.

1. Evaporative cooling of PV modules will increase the efficiency.
2. FPV will conserve the water.
3. FPV prevents algae growth in the drinking water reservoir.
4. FPV prevents the reservoir banks erosion.
5. FPV on hydropower plant will consistently reduce the transmission charges.

3. GFPV on campus

Based on the above learnings and availability of potential lake inside the campus triggered to develop a GFPV system on the campus with the cooling and tacking facilities. The main reason to carry out the work is needed to develop as a pilot project for creating and exploring the possibilities across Malaysia. [5] As of now the cumulative installed capacity of solar PV is 390 MW with the annual power generation of 1,080,417 MWh and corresponding CO_2 emission reductions are 2,761,995 ton as per the SEDA.

The facility for FPV is not only inside the campus but also there are possible reservoirs and main lakes are in 5 places namely Durian Tunggal reservoir, Jus reservoir, Kenyir Lake, Pedu Lake, Temenggor Lake. So from the motivation and consistent results achieved form the pilot project, there is a possibility of proposing the government to undertake FPV and as well as hybrid small hydro and FPV.

Initially, we developed a simulation-based feasibility report where we analyzed the total possible capacity of grid-connected Solar power plant using [6] Folsom Labs Helioscope. During the process, we found there is a

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possible capacity of 943 KWp for the all possible rooftops, carports and mainly lake for GFPV. Among the total cumulative capacity, erection of GFPV on the lake alone contributes to 144.6 KWp which is the first proposed maximum possible GFPV on the entire country. So by analyzing the various literature reviews, we are planning to propose a GFPV with tracking and cooling system to make the lake as sustainable. Following are the various analysis and data found during the process of simulation in both Helioscope and PVSyst [7]. The following picture shows the overall proposed deployment of possible grid connected Solar Photo Voltaic power plant. In that our particular area of interest is FPV which is on shade free lake. As per the review, we need to identify which possible and feasible erection methods is suitable for the lake. Then designing the structure with tracking and cooling mechanisms.

As per the proposed design, the FPV is rated at 144.6KWp with the annual production of 185.2 MWh which is having the performance ratio of 80.1%. The monthly production almost equal for all the months ranging around an average of 15.4 MWh. As per the weather data set the annual global horizontal irradiance in the simulation is 1,597.4KWh/m^2 with this irradiance the energy fed to the grid will be approximately 185,206 KWh. From the simulation, it is clear that average operating ambient temperature is 29 ^{o}C, whereas Average operating cell temp is 37.9 ^{o}C. which was simulated considering the rooftop model, as there is no provision to simulate FPV in Helioscope. Thereby after implementing the FPV, we will be in the position to measure the Average Operating cell temperature which will be lower as we are provided with natural water cooling system to remove excess heat. Obviously, by reducing the cell temperature, there is a possibility of an increase in efficiency and production.

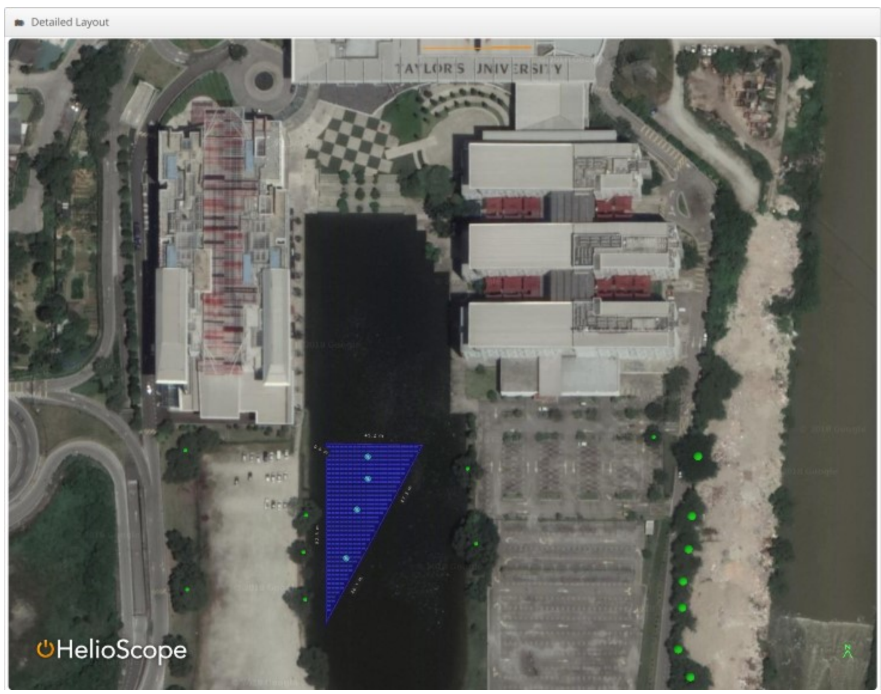

Fig. 6. Proposed FPV on Taylor's lakeside campus.

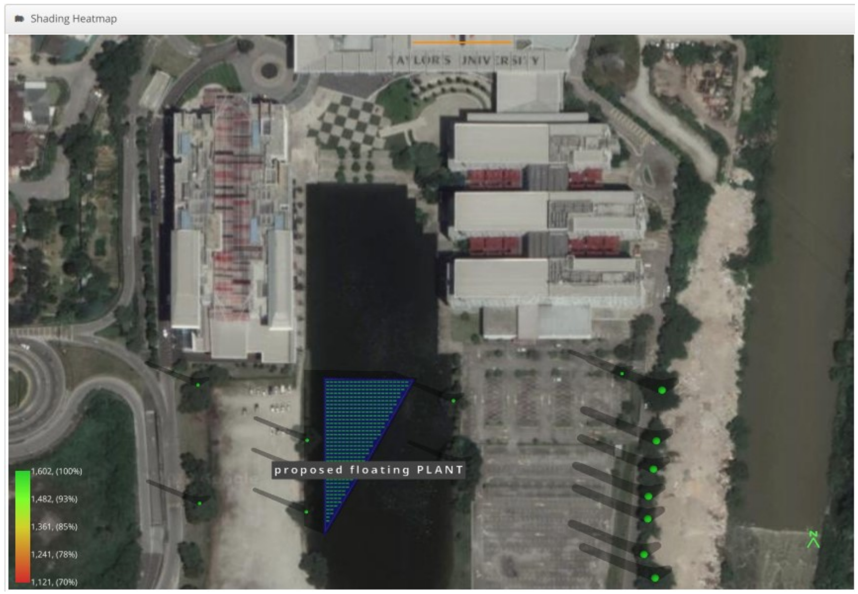

Fig. 7. Shading heat map of Proposed FPV on Taylor's lakeside campus

The above FPV is modeled in PVSyst for the simulated output. The software shows the various graphs which represent the various process involved in it. The following details are given as input while the simulation is done. The latitude and longitude for our university are 3.1° N and 101.5° E. the meteo data required to process the simulation is meteoNorm 7.1 station Kuala Lumpur which is situated at 4 KM. the collector plane is made at the tilt of 1^0 considering the maximum generation and as well as cost constraints during erection. Fig 8 shows the horizon path of the sun at Kulegal time with various patterns ranging from January to December based on the horizon shading analysis can be done along with the suitable azimuthal angle.

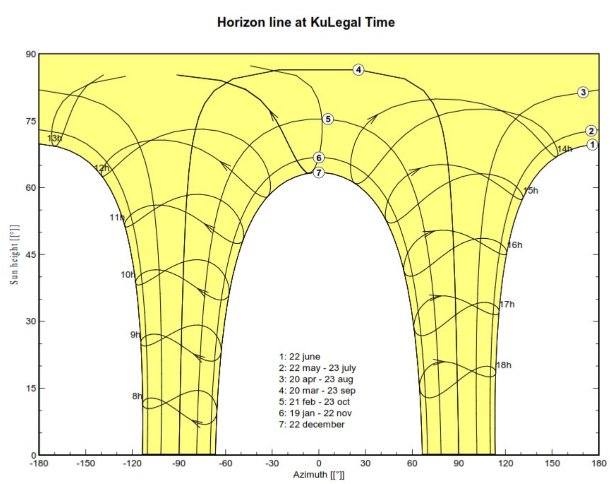

Fig. 8. Horizon line at KuLegal Time

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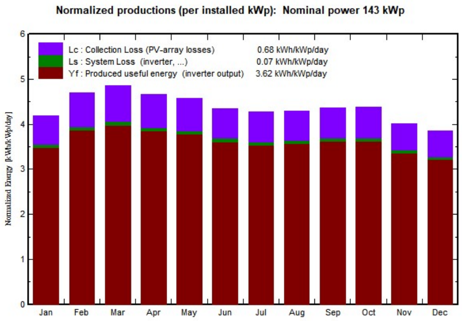

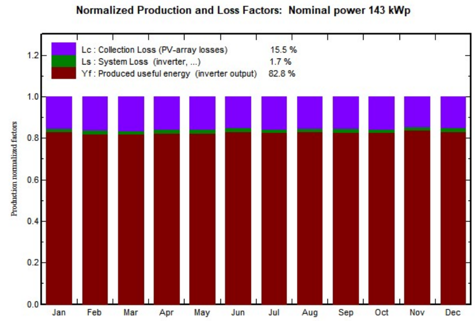

Fig. 9. Normalized production (per installed KWp)

Fig. 10. Normalized production and loss factor (per installed KWp)

FPV System has designed in PVSyst with the above assumptions and simulated the system for 143 KWp with 18 modules in series and 23 strings in parallel comprises of total 414 modules of 345Wp. The generated DC power is fed to the 3 units of 40 KVA with the operating voltage ranging from 250 – 900 V. Fig 9 represents the normalized production per installed KWp. Which shows that power output from the inverter is 3.62 KWh/KWp /day. In that, there is negligible loss in the system named as system loss which is 0.07 KWh/KWp /day. In fig 10 it shows the normalized production and loss factor where it contributes 82.8% for the production with 1.7% of system loss and 15.5 % of losses at PV array base because of increase in module temperature.

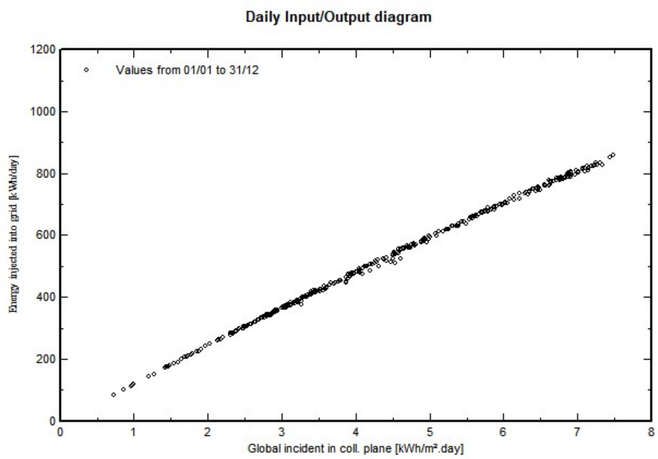

Fig. 11. Daily Input / Output diagram

Fig 11 shows the daily Input / Output diagram which shows that global incident in collector plane is directly proportional to energy injected into the grid for 1 year.

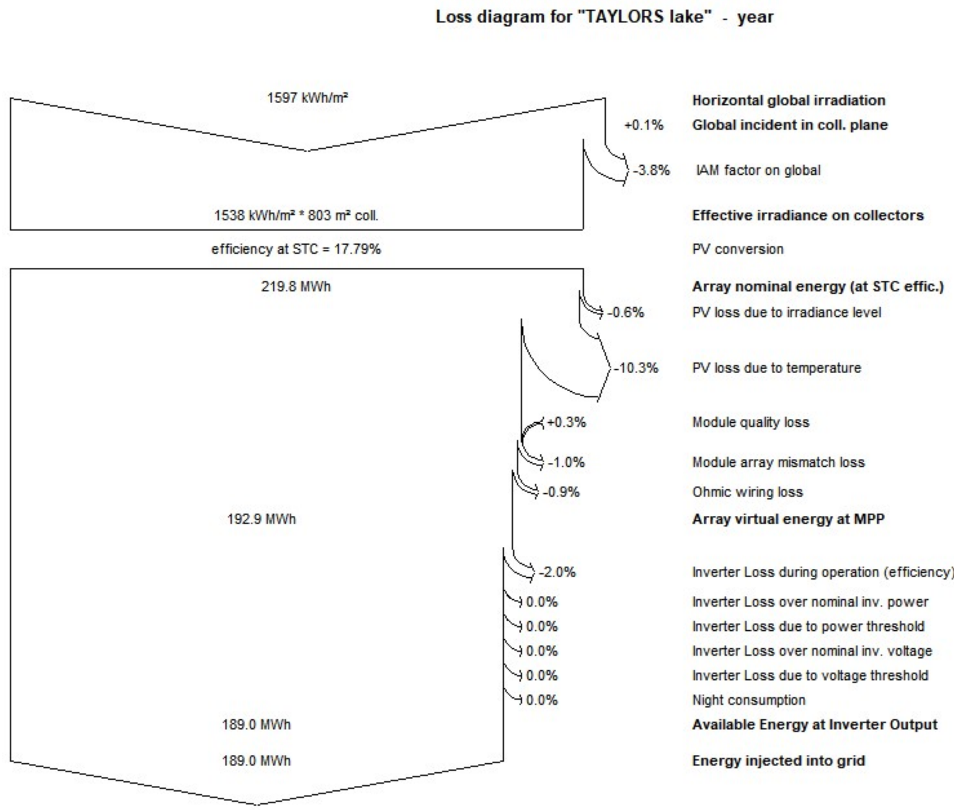

Fig. 12. Loss diagram for year

Fig 12 shows the loss diagram with 0.6 % PV loss due to the irradiance level, 10.3 % is due to the module temperature loss because the characteristics of the module are determined using standard temperature of 25°C. PVSyst will consider the meteo data of the nearest station. Module quality loss is because of slight variation in the manufacturer's specification. Loss occurring at the inverter section is due to its working conditions like loss over nominal inverter power, loss due to a power threshold. Overall the system is working with 82.8% is the performance ratio.

Table 1: TAYLOR'S lake Balances and main results

Month	**GlobHor kWh/m²;** Horizontal global irradiation	**T Amb °C;** Ambient Temperature	**GlobInc kWh/m²;** Global incident in coll. Plane	**GlobEff kWh/m²;** Effective Global, corr. for IAM and shadings	**EArray kWh;** Effective energy at the output of the array	**E_Grid kWh;** Energy injected into grid	**EffArrR %** Effi c. Eout array / rough area	**EffSysR %** Effic. Eout system / rough area
Jan	129.4	27.25	130.2	124.9	15738	15423	15.05	14.75
Feb	131.3	27.73	131.9	127.1	15799	15479	14.91	14.61
Mar	150.3	28.07	150.5	145.1	17973	17608	14.86	14.56
Apr	140.2	27.57	140.0	134.8	16847	16507	14.98	14.68

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May	142.5	28.58	141.9	136.6	17066	16724	14.97	14.67
Jun	131.0	27.81	130.3	125.4	15803	15486	15.10	14.79
Jul	133.3	27.83	132.7	127.9	15987	15663	14.99	14.69
Aug	133.8	27.79	133.4	128.5	16161	15837	15.08	14.78
Sep	131.2	27.20	131.2	126.4	15839	15519	15.03	14.72
Oct	135.5	27.48	135.9	130.9	16392	16060	15.02	14.72
Nov	119.9	26.69	120.5	115.8	14728	14435	15.21	14.91
Dec	118.9	27.17	119.7	114.8	14522	14231	15.11	14.80
Year	1597.3	27.60	1598.2	1538.1	192856	188972	15.02	14.72

Above table 1, explains the balances and main results of the simulation. Which consists of global horizontal irradiation, ambient temperature and a global incident in collector plane, global effective corrected iam (incidence angle modifier) and shadings, effective energy at the output of the array, energy injected to the grid. All these parameters are purely on the data available in the meteo. Generally, there will be slight variation with the real-time and simulated system.

4. Conclusions

There is a huge potential in implementing an FPV in approximately 70 lakes across peninsular Malaysia. In order to study the feasibility of FPV, this simulation-based can act as the first point of reference to implement FPV in the reservoir. Based on the simulation we are going to propose different types of FPV with various advance tracking and cooling systems. After successful commissioning of FPV system, the first of a kind on campus FPV can act as a research facility to carry out future work. We are also planning to propose a solution to implement hybrid FPV system with small hydro on the reservoirs with existing hydropower infrastructure.

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