Floating Solar Cell Power Generation, Power Flow Design and its Connection and Distribution

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Abstract-Solar power installed in sea water has advantages as compared to installed on lands such as good and unshaded solar source by buildings or plants, better cooling, good utilization of surface than lands, but it also suffers from other scenario such as the sea water corrosion, wave and tidal disturbance. The present paper is to discuss the project for the sea water solar power generation. The configuration of the solar power system for sea water is examined. The solar cells design, connection power distribution, protection, environment impact and shore side power management are discussed. The power delivery using V2X is proposed.

Keywords-Solar power, sea water solar power, floating solar system, Photovoltaics,

I. INTRODUCTION

The electrical power generation is based on coal fire, natural gases or through fossil fuel to power a generator through mechanical connection to generate power from electrical generator. This method produces green house gases and the efficiency is relatively poor. Photovoltaic (PV) cells or so called the solar power cells are no commonly used to provide alternative energy sources because its maintenance is low, life time is long and its reliability is high [1-2]. It is relatively not to rely on seasons like the wind power. Because of its semi-conductor in nature, it is also called static power sources and it make them easily to be installed in the top of a building, curtain wall or lands in form of solar farm. The generated power is the connected to grid and recently the grid connected solar power is a good research area. The power can be used directly on grid or stored in energy storage devices such as battery, water storage, super-conductor or super-capacitor [2]. It can also be used for grid connected and this can reduce the requirement of expensive energy storage.

The solar cell power generation is using series and parallel connections of solar cells. Series connection allows the total connection to increase to sufficient voltage to drive DC –AC power inverter. A DC-DC power converter is used to regulate the voltage form the solar panel before it is connected to the inverter. Another DC-DC converter is also to provide a MPPT (Maximum power Point tracking) such that the input voltage to the DC-DC converter is regulated to provide a maximum power under various solar illumination intensities. So far, there is very few research reported to address the project and efficiency development under sea-water condition. The report on fresh water is more common [3-4] because the environmental condition for fresh water is easily to be managed. The corrosion is less, there is no tidal or wave movement consideration.

Under sea water environment, a floating unit is used to fix the solar panel above the sea water level. This is important as the long term immersed in sea water could shortened to life time of the electrical connections and solar panel. The floating unit is flat and floats on sea water. The solar panel is to be designed to have a certain tilt angle compared to the horizon. This tile angle has to be selected between the solar power and the wind speed condition.

The present project is to provide the best method of the design for the sea water floating solar panel power generation system. The design parameter for this exercise is to be discussed.

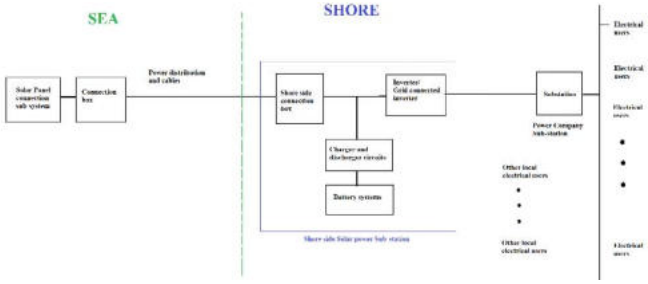

Fig. 1: The configuration of the floating sea water solar power system

II. SOLAR PANEL CONNECTION SUBSYSTEM

The solar panel consists of a number of solar cells which are connected in series to produce the requirement of voltage for each panel. Its output voltage for each panel is 50V. But its voltage depends on soar illumination intensity. The output could reduce to zero when there is no sunlight. The electrical power obtained from the solar panels is distributed through electrical distribution network from the sea water to the shore in form a DC distribution. Armor cable is used for the distribution. There is energy storage to assist the DC voltage stability, noise filtering, buffer and transient noise absorption. It is also acted as the energy storage during shaded or no sunlight condition. The power is connected to grid and distributed to users. The solar panel is connected with a sub-circuit DC-DC converter to assist the MPPT (Maximum power point tracking) that is able to obtain the maximum power from the solar panel using voltage and/or current mode control. Fig 2 shows the panels are connected in series and then in parallel that is so called a solar panel array.

Usually a solar array consists of a rectangular connection of a number of solar panels to form an array, that is like a matrix. To meet safety standards or cable rating, using

1000V is the best choice, the present design is to use 1000V as a maximum DC distribution voltage for the series connection of solar cells. For 50 V for each panel, the connection of to 8 to 10 in series is chosen. Parallel connections of the series connected panels for high output power rating.

The power delivered to the shore side are distributed to the grid. As the grid installations is expensive, a power mobility can be used that is to use battery vehicle to deliver the charged batteries to other locations by a lorry with batteries. The lorry can be driven to designated location for power delivery. Therefore the method is not limited by the grid connection, but can deliver power anywhere with less planning and building work.

In fact the concept of Vehicle to Home (V2H), Vehicle to Building (V2B) [5] and Vehicle to Vehicle (V2V) [6] are part of the consideration to deliver power to users directly without using Grids. Grid installation, maintenance and planning are costly and timely. Therefore for fast and effective use of sea water solar power, the V2X concept using battery vehicle as a moving battery is a simple method to deliver power to users.

The concept of power mobility everywhere is an alternative method of power delivery without using grid, but electric vehicles or battery vehicles.

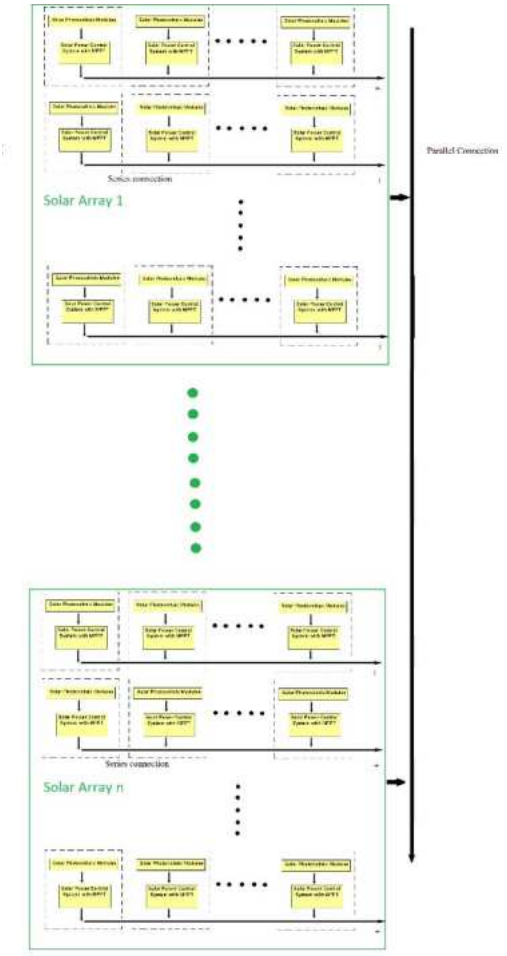

Fig. 2: The schematic of Solar panels connected for solar system.

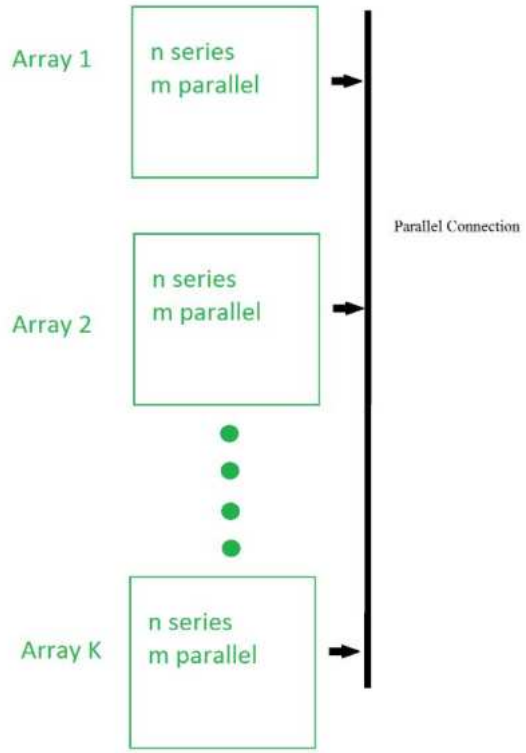

Fig. 3: The Solar array connection in parallel

The solar panel with their internal controller should consist of local subcircuit MPPT for the power optimization. All the panels form Array such that each array should be a multiplication product n ×*m* of a number in n panels in series (*n*) and a number in m panels in parallel (*m*). There are K arrays to form the total structure as shown in Fig 3. This define the total maximum power from the PV farm. Therefore the total power output P_{total} is:

$$P_{total}=nmKP_{PVp} \quad (1)$$

where P_{PYp} is the peak power of each PV panel. The electrical protection is needed to be installed in the system. A semi-conductor diode is used to ensure the electrical current is only to flow outside from the solar panel, rather than going into the panel. This is to ensure to avoid the reverse current damaging. This is represented by Du which can be a diode or an electronic circuit to ensure unidirectional power flow.

Another sub-circuit is the by-pass circuit or diode D_B. This is to ensure that in case one panel is broken or open-circuited, the associated electrical current path will not be disconnected. The current is still able to flow through the by-pass diode/circuit that is connected in parallel with the panels. Of course, the by-pass diode/circuit can also be done by power transistor or power converter. Fig 4 shows the configuration. It illustrates that the panels (in yellow) are connection in series and parallel with a subcircuit of MPPT for the power optimization.

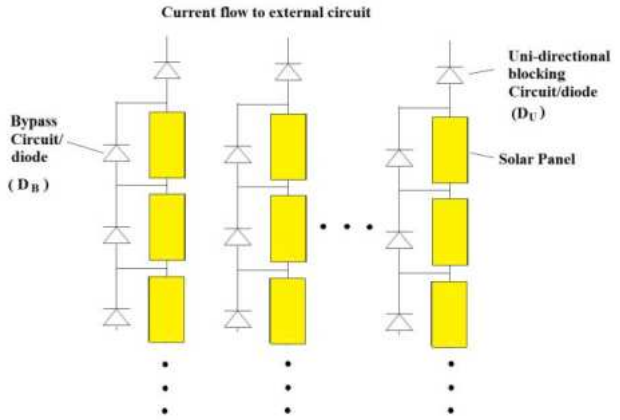

Fig. 4: Protection sub-circuit for uni-directional blocking and bypass

III. Maximum Power Point Tracking

MPPT (Maximum power point tracking) is a typical method to produce higher power with a given sunlight intensity. This method requites the sensors to find the maximum power output through searching techniques but this method could end up with uncertainly and wrong decision. An open loop method is therefore proposed. It is basically using 80% of the maximum voltage Vpx and this is usually the maximum power point. This can be done during offline measurement and then to use a DC-DC power converter to adjust the operational voltage to match this design. The DC-DC power converter forms the MPPT function and is also called MPPT controller. This is done by a controllable DC-DC power converter to regulate the current and voltage requirement through the mark-space ratio of the switching devices. Fig 5 shows an MPPT design for a solar panel. The characteristics of the solar curve is a standard i-*v* trajectory. The MPPT control algorithm is to search for the maximum power point.

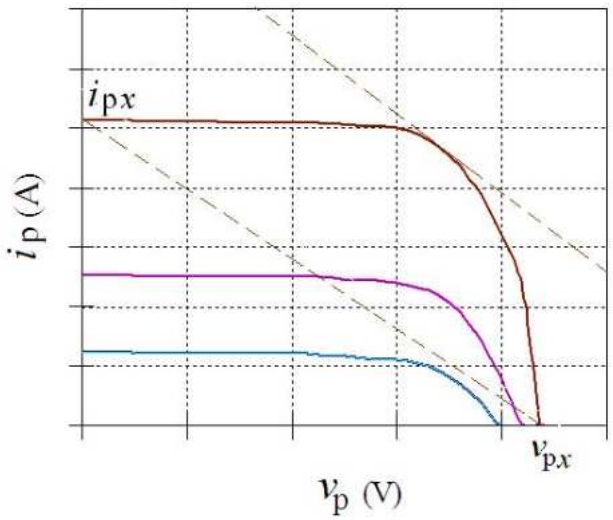

Fig. 5: A typical MPPT of solar cells

The MPPT is to provide power conversion to the solar panel. The connection method is shown in Fig 6. The Solar panel is with two output terminals. Say one is positive and one is common. The common connection is connected to the MPPT common terminal. The other positive terminal is connected to the MPPT for maximum power processing. The output of MPPT is connected to other series network. Fig 6 shows the connection. MPPT circuit is a just a DC-DC power converter as said before.

When MPPT is not available or not in used, Fig 4 can be used for the connection method.

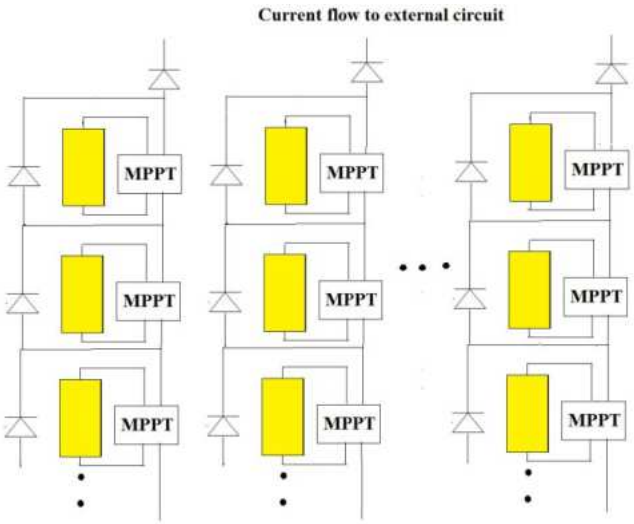

Fig. 6: MPPT connection to solar panel.

IV. Tile Angle of Solar Panel

For sea water environment, the solar panel is sit on the floating unit. The floating unit is flat and the solar panel is designed to have a tilt angle θ compared to the horizon. The theoretical best tile angle is equal to the latitude angle ϕ of the location. For example, in Hong Kong, the tilt angle is 22.3° facing south. This tile angle has to be selected between the solar power and the wind speed condition.

The wind force F_w is given by the empirical formula:

$$F_w = 0.5\ \rho\ V^2\ A \qquad (2)$$

where ρ is the air density that is estimated to be 1.18 kg/m^3 at around 25 degree. A is the effective area of the solar panel under the wind direction. Because of the angle tiled, the effective area is estimated to be $A_s \sin\theta$ where A_s is the area of the solar panel as seen in Fig 7.

However, the wind speed is not always horizontal, the above estimation gives empirical method for the estimation, the safety tiled angle is therefore:

$$0 \le \theta \le \phi. \qquad (3)$$

Experimental results shows that in order to protect the solar panel from damaged due to strong wind, gust or typhoon, the tilt angle should be reduced:

$$\theta \le \phi/2. \qquad (4)$$

The reduction on tilt angle depends on many factors and it is governed by the geographical location.

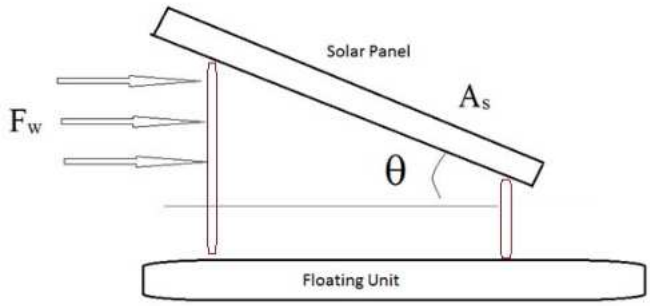

Fig. 7: The angle between solar panel and floating unit

VI. Integrated Alternative Energy Sources

One of the advantages of the floating solar PV system is to make use of the water for cooling. With one side being hot while facing the sunlight and the other side under the PV is cooler with water cooling, the large temperature gradient provide a mechanism for the Thermal electric generator(TEG). TEG is installed between the solar panel to provide additional power generations. This is an additional resource.

Other alternative power generations can be added are wave power. The waste energy due to wave and tidal movements from the sea can be harvested using linear motion generators or adapted rotational electric generator. The power is usually small but this additional power can be a good supplement of power.

V. Environment issues

As the solar system is installed on the sea water, the concern due to environment impact is to be examined. The present floating solar power is similar to a ship. Therefore the environment concern is minimal. Anchors are used to fix the solar panels and floating units. The fixing of the anchor is similar to a ship or boat. No disturbance or alternation is installed to the seabed.

The power distribution cable floats on water. However, because of compromise with the boat traveler, a section of the cable dips into the water to allow the boat to travel through. The cable after reaches the shore, are installed the same way as the normal power distribution on lands. There is no particular concern.

The battery storage, as an energy buffer, is also one of the key components of the development. There is a concern on the battery when they are near the end of life. The disposal of used battery is a concern. It is now awaiting the new government policy for used battery management. The used battery or retired battery from electric vehicles can be used in this application because the energy density is not a concern. For EV battery, when it is retired, the state of health is still 70-80% and this is possible to be used for this Solar power energy storage. Of course, another alternative is to develop new recyclable battery that will not impose the loading of waste battery.

VI. Conclusion

The proposed project is to develop a solar panel system that is installed on sea water condition. The panel is supported by floating units that isolate the panel from the sea water. MPPT is needed to be installed with the solar power in order to optimize the maximum power obtained with a given sunlight. The MPPT circuit has control and power connection that that matches with the solar panel for better power management. The panels are connected in a rectangular format with a fixed multiple of two integers to form series and parallel connection. Depending on the sea water environment and geographical needs, the present arrangement is a long rectangle. The series power connection defines the voltage needed for the input side of the inverter. The parallel arrangement defines the power and current level.

The tile angle of the solar panel should be selected to be less than the latitude angle of the location. This is usually 50% of the latitude angle. For larger latitude angle of a location, the tile angle assessed according to the wind speed. Suitable gap is needed between the lower end of solar panel to the floating unit and also between the solar panels in order to allow the draft and dirt to be discharged.

The present system is to be built in New Territories of Hong Kong and is believed to be one of the largest and first floating solar power system on sea water in the region.

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