System sizing of 1MW grid interconnected solar photovoltaic power plant

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Abstract: *Renewable energy sources are expected to be a promising alternative energy source. These renewable energy sources provide a good substitute to the centralized power generation systems which consumes fossil fuels and has imposed several problems on the environment. In Myanmar, solar renewable energy source is more convenient than any other renewable energy sources. But the generated power of the renewable energy source is usually fluctuate due to the environmental or weather conditions. Therefore, system sizing of this renewable energy plant is necessary to get the efficient power from the instability nature of itself. In this paper, system sizing of a 1MW solar photovoltaic (PV) plant interconnected to utility grid is presented. And then, the configuration of proposed grid interconnected solar photovoltaic (PV) system is also stated. Moreover, procedure, formulae and calculations for system sizing of grid interconnected solar photovoltaic (PV) system are described in details. Finally, performance of this proposed system is demonstrated by MATLAB/ SIMULINK.*

Key Words: *Renewable Energy Source, Solar PV Plant, Inverter System, System sizing.*

1. INTRODUCTION:

The worldwide imperative to reduce greenhouse gases, particularly CO_2 and to secure energy supplies for the long–term future has prioritized the development of electricity generation from renewable energy sources [1].Renewable energy sources include solar power, wind power, small hydro power and so on. In Myanmar, hydropower system is the main generation system and used as the traditional power supply. Solar power can be used as alternative energy source in Myanmar. For this reason, solar power plant is used as renewable energy source that is connected to main grid in this paper.

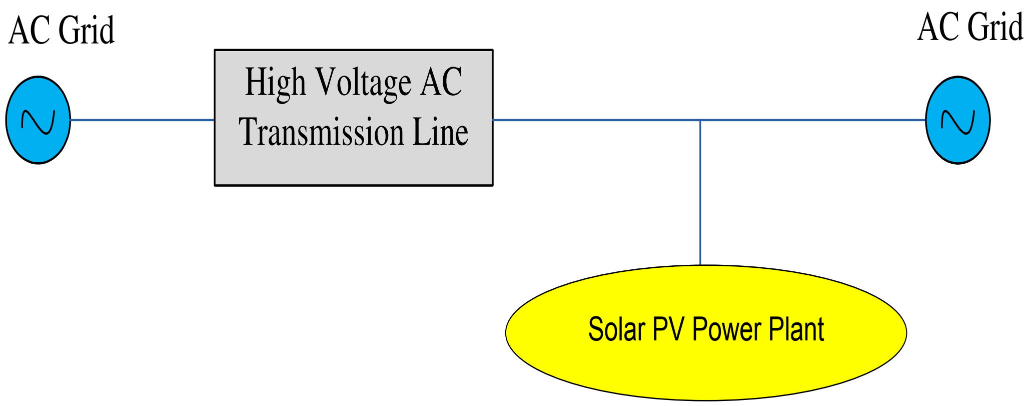

Fig.1 A Typical Configuration of High Voltage AC Transmission System Interconnected with Renewable Energy Source

Solar power system is the most interested renewable energy source in the world. It have high incremental cost but small maintenance cost. Its drawback is that it relies on weather conditions. Solar radiation is measured in incident solar radiation and it varies with location based on latitude. Highest radiation is got in the region between 30 degree south and 30 degree north. Solar energy source depends on the energy conversion type; solar thermal conversion and solar photovoltaic (PV) conversion. Solar thermal uses the sun's heat energy to generate steam power for running turbines. Solar photovoltaic uses solar cells that convert radiation energy directly to electric energy [4]. In electrical engineering system, solar photovoltaic system is widely used instead of solar thermal system.

Although there are two types of connection on solar photovoltaic (PV) power system as off grid and grid interconnected, grid interconnected solar photovoltaic (PV) source to High Voltage AC transmission system is more interested than off grid system because excess power from this source can integrate into main grid after it has been used in local and there is no need to use energy storage devices for this type of energy system. The simple structure of a typical High Voltage AC transmission system interconnected with solar photovoltaic (PV) source is shown in Fig. 1.

As the penetration of solar photovoltaic (PV) source into the system increases, there are major issues for the operation of power system. Interconnected solar photovoltaic (PV) source on utility grid has the main drawback as their low efficiency and controllability [1]. And the capacity of this source is growing at a fast rate, its relevant influences on the host grids need to be carefully investigated. This also poses serious technical issues for the transmission network because of its fluctuating characteristics which may cause the instability of the power system [3]. Incorporating weather dependent solar photovoltaic (PV) source into existing power systems, its output fluctuations make effects on system operation and frequency. Therefore, power system improvement methods and careful system sizing are becoming necessary in the power system interconnecting with solar photovoltaic (PV) source since they can provide and maintain the stability condition according to system requirement.

2. GRID INTERCONNECTED SOLAR PHOTOVOLTAIC (PV) PLANT:

A grid-connected solar photovoltaic (PV) power system is an electricity generating solar PV power system that is connected to the utility grid. A grid-connected PV system consists of solar panels, one or several inverters, a power conditioning unit and grid connection equipment. They range from small residential and commercial rooftop systems to large utility-scale solar power stations. Unlike stand-alone power system, a grid-connected system rarely includes an integrated battery solution as they are still very expensive. When conditions are right, the grid-connected PV system supplies the excess power beyond consumption by the connected load to the utility grid.

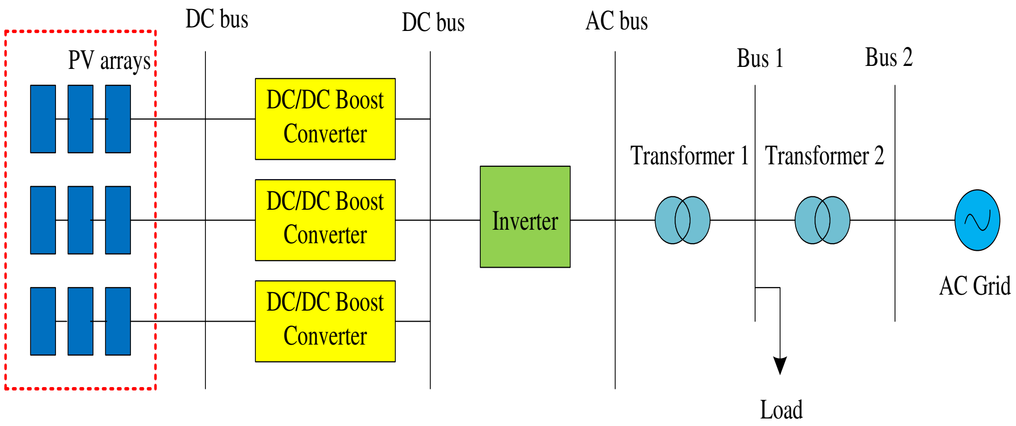

Fig.2 Proposed Grid Interconnected Solar Photovoltaic Power System

Fig 2 states the proposed grid interconnected solar photovoltaic power system. In this figure, PV arrays are arranged by connecting the solar panels in series and parallel connections to get the require voltage and current. DC/DC boost converters are used in this research because of the usage of multi-string inverter system. Numbers of DC/DC boost converters is equal to the numbers of arrays. These DC/DC boost converters boost the output voltage of solar plants to required value. The output of DC/DC boost converters is fed to inverter system and then this inverter system transform DC value to AC value. This AC output is stepped up to distribution level by using step up transformer and fed to local load. And the excess output is again stepped up with boost transformer and connected to the utility grid finally.

3. SIZING OF GRID INTERCONNECTED SOLAR PHOTOVOLTAIC (PV) PLANT:

In this section, the procedure for sizing the whole grid interconnected solar photovoltaic power plant is discussed. Proper sizing the PV plant is very important in order to improve the system performance.

Firstly the inverter system is chosen as the main sizing item of the whole system. There are three types of inverter systems for grid interconnected PV plant; centralized inverter system, string inverter system and multi-string inverter system. Among these inverter systems, multi-string inverter system is the most flexible design with high efficiency. Combination of the advantages of central and string technologies makes a compact and cost effective solution. And individual PV strings can be turned on and off to use more or fewer modules [3]. For these above advantages, multi-string inverter system is the most useful inverter system for large scale PV plant interconnected to utility grid. Fig.3 shows the multi-string inverter system for grid interconnected PV plant.

And then, nominal system voltage is selected to size the whole system. To calculate the inverter input DC voltage, inverter amplitude modulation index is assumed. To process maximum power by an inverter, inverter amplitude modulation index should be at maximum value without producing unwanted harmonic distortion. Therefore, inverter amplitude modulation index should be in the range 0.95 to produce the highest AC output voltage of inverter [4].

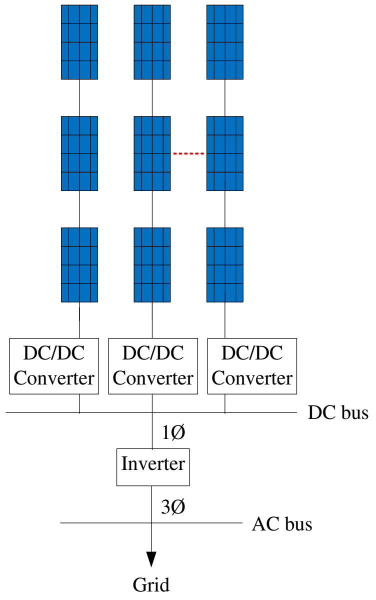

Fig.3 Multi-String Inverter Topology

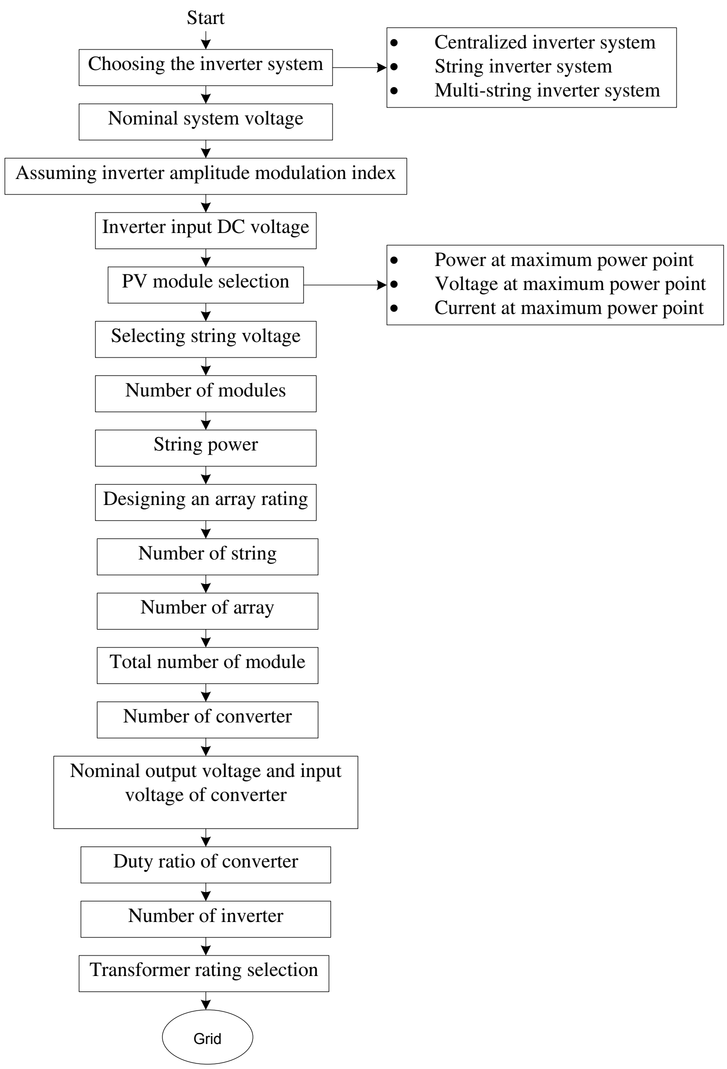

Fig.4 Flowchart for Sizing Procedure of Grid Interconnected PV Power Plant

To get the sufficient PV generated power, PV module is selected by choosing the voltage and current at maximum power point. By selecting the string voltage, number of modules and string power can be calculated. The rating of an array is designed to calculate numbers of string, numbers of array and total numbers of module. Since numbers of converter is equal to the number of array, nominal output voltage, input voltage and duty ratio of these converters can easily be computed. Number of inverter is calculated by using PV generated power and power of one inverter. Finally, transformer rating is selected as individual design and it is interconnected to the main grid. Fig.4 shows the sizing procedure of grid interconnected PV power plant.

4. FORMULAE AND CALCULATIONS FOR SYSTEM SIZING:

To size the whole grid interconnected solar photovoltaic power plant, the inverter system is firstly chosen. In this proposed system, multi-string inverter system is used. Inverter input DC voltage can be calculated by using the following equation.

For *1Ø* system,

$$V_{idc} = \frac{\sqrt{2}V}{M_a}$$

For *3Ø* system,

$$V_{idc} = \frac{2\sqrt{2}V}{\sqrt{3}M_a}$$

where,

V_{idc} = Inverter input DC voltage, V

V = System voltage, V

M_a = Inverter amplitude modulation index

Numbers of module N_m is

$$N_m = \frac{V_s}{V_{MPP}}$$

where,

V_s = String voltage, V

V_{MPP} = Voltage at maximum power point, V

String power P_s can be calculated by

$$P_s = N_m \times P_{MPP}$$

where,

P_{MPP} = Power at maximum power point, W

Number of string N_s and number of array N_a is

$$N_s = \frac{P_s}{P_a}$$

$$N_a = \frac{PVgeneration}{P_a}$$

where,

P_a = Array power, W

Total numbers of modules can be calculated as follows;

$$Total\ numbers\ of\ modules = N_m \times N_s \times N_a$$

Number of converter is N_c equal to the number of array N_a.

$$N_c = N_a$$

Boost converter output voltage is equal to the inverter input DC voltage and boost converter input voltage is equal to the string voltage.

$$V_o = V_{idc}$$

$$V_i = V_s$$

where,

V_o = Boost converter output voltage, V

V_i = Boost converter input voltage, V

Duty ratio of boost converter *D* is

$$D = 1 - \frac{V_i}{V_o}$$

Number of inverter is obtained by dividing the PV generation to one inverter power P_i.

$$N_i = \frac{PV generation}{P_i}$$

5. SIMULATION AND RESULTS:

The Simulink model construction is executed as the proposed system. It can vary according to the individual design. Load condition is assumed as 100kW for a residual. The simulation diagram is demonstrated by MATLAB/SIMULINK. The main parameters of the paper show in Table 1 and this schematic diagram of the model PV system is shown in Fig. 5.

TABLE 1
Main Parameters of the System

PV	
Module	SunPower SPR-315E-WHT-D
P_m	315.072W
V_{MP}	54.7V
I_{MP}	5.76A
N_m	8
N_s	50
N_a	8
TNM	3200
DC-DC Boost Converter	
N_c	8
D	0.5
Inverter	
N_i	2
Transformer	
Distribution Transformer	1MVA, 230V/33kV, 50Hz
Boost Transformer	1MVA, 33kV/230kV, 50Hz
Load	
P_l	3phase, 100kW, 50Hz

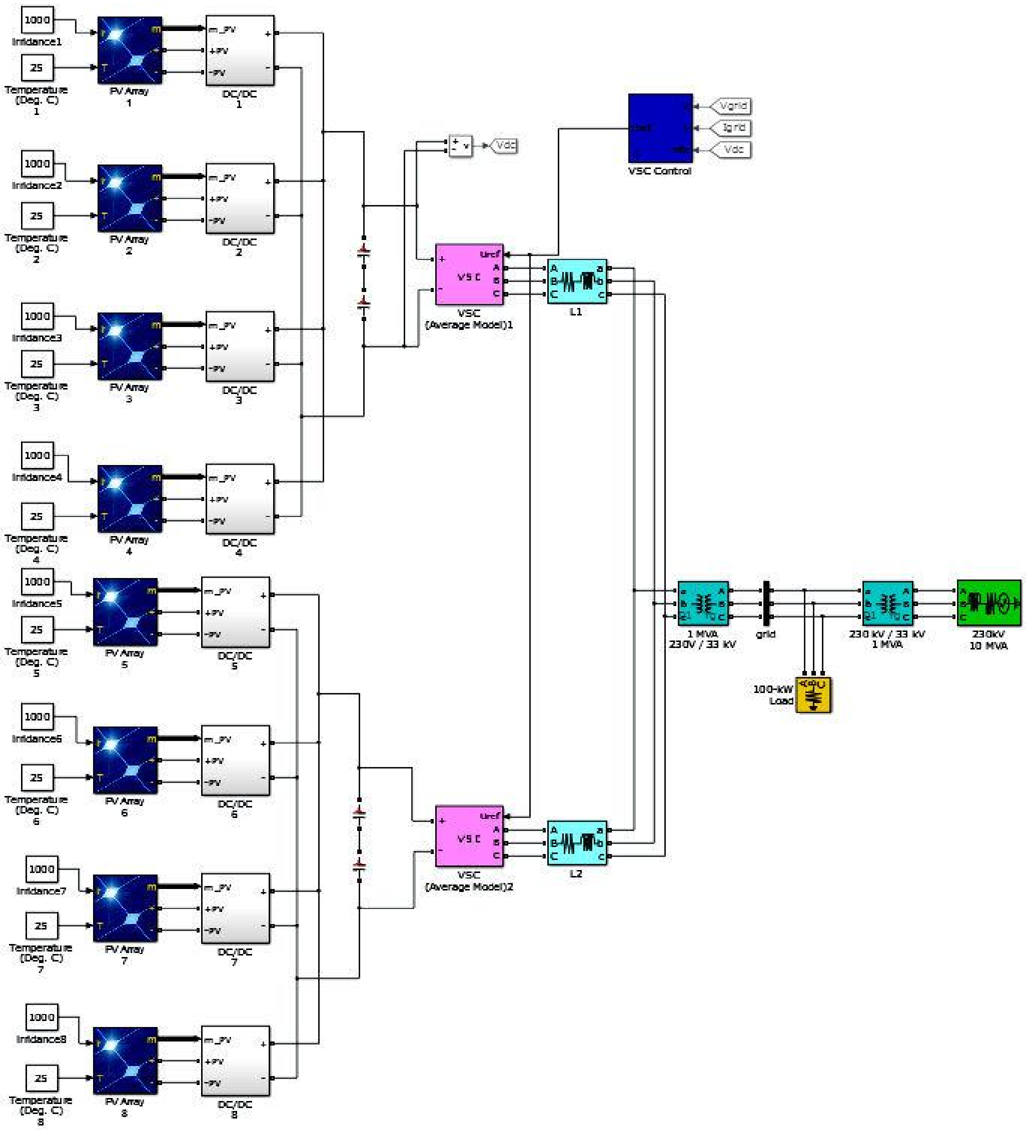

Fig.5 Simulink model of PV System Interconnected to Utility

In this figure, the installed capacity of PV system is 1MW. After installing the PV source, Boost converter are used as DC-DC converter to transform the variable voltage source to constant voltage source. To get the maximum power, Incremental conductance method is used in this boost converter as maximum power point tracking method. And the DC link capacitor is used to maintain the constant DC voltage. PLL technique is used to synchronize the whole system with grid within the inverter. 100kW load is used to distribute the local area.

The simulation results of the grid interconnected PV system are shown in Fig.6-9. In this result, power of an array is about 920kW because of losses. It is fed to local distribution line passing through step up transformer and then it is interconnected to grid. At grid side, voltage is about 30 kV and current is about 18A. Power at grid side is about 700 kV as shown below.

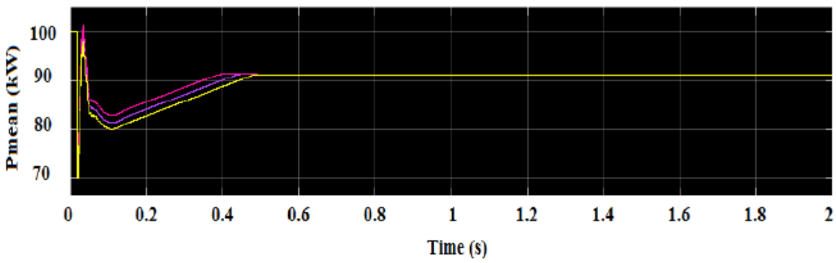

Fig.6 Simulation Result of PV System

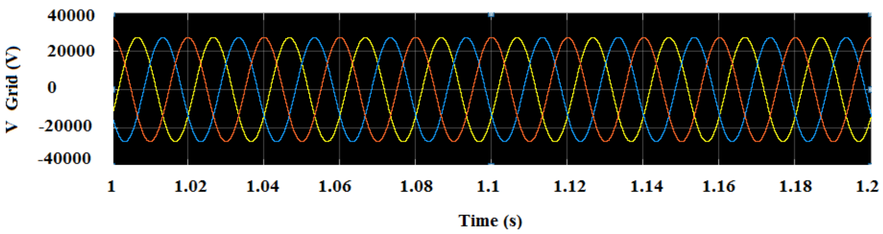

Fig.7 Simulation Result of Grid Voltage

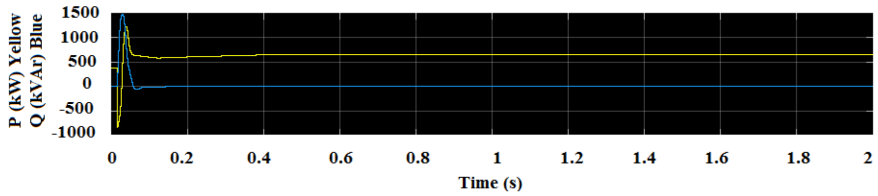

Fig.8 Simulation Result of Grid Current

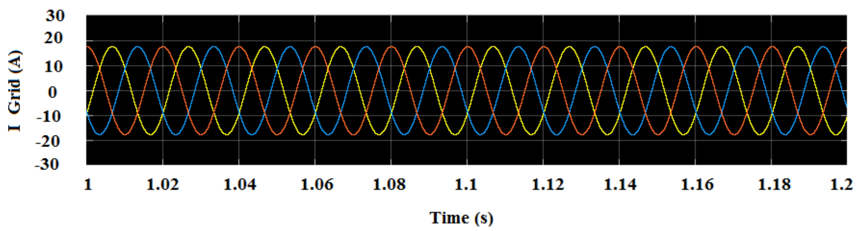

Fig.9 Simulation Result of Grid Power

6. CONCLUSION:

System sizing is important for grid interconnected solar photovoltaic power plant. To get the high efficiency of solar panel, MPPT technique is used in this system. Choosing the right inverter system is the main point of system sizing. Therefore, multi-string inverter system is used to have good efficiency and good system performance in this paper. For this inverter system, boost converter is needed to boost DC voltage to require value. The inverter system is also controlled by using PLL synchronization technique. Choosing the transformer rating depends on the individual design of system engineers.

7. ACKNOWLEDGMENT:

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