Modelling and Simulation of Roof-Top Solar Photovoltaic System for Industrial Building Using PVSol and Matlab

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Abstract – Solar energy uses solar thermal energy, solar photovoltaic system and various applications in stand-alone mode and grid-connected modes. The components in a solar PV system include a solar PV module, inverter system, structures and energy meter, which can be either grid-tied or off-grid with battery storage. These systems do not need batteries and they are connected to the utility grid power. Nowadays, electricity unit prices are increasing in industrial buildings. So, the solar system will use to reduce electricity prices. In this paper, the modelling of a rooftop solar photovoltaic system has been proposed using PVSol software and MATLAB/Simulink. These algorithms were implemented in PVSol for modelling the solar modules and the results analyzed on MATLAB/Simulink to obtain the voltage, current and power.

Key Words - Rooftop solar Photovoltaic, Industrial building, PVSol, MATLAB/Simulink

I. INTRODUCTION

Renewable energy sources emerge as a critical alternative to fill the energy gap with the research and advancement in power electronics devices, systems and control technology [1]. Solar energy uses solar thermal energy, solar photovoltaic system and various applications in stand-alone mode and grid-connected methods [2]. The components in a solar photovoltaic system include a solar photovoltaic module, inverter system, structures and other associated devices, which can be either grid-tie or off-grid with battery storage [2]. Photovoltaic power generating methods are used in various modes and are fundamentally categorized as stand-alone and grid-connected systems for residential (rooftop), agriculture, commercial and industrial purposes [4]. The photovoltaic system categorization represents in a hierarchical chart based on the working modes and applications [3].

The stand-alone system utilizes with or without storage and a hybrid system according to the application requirement [4]. The stand-alone system without storage will have deficient utilization capability of the generated power. The overall block diagram for the grid-connected rooftop solar photovoltaic system shows in Figure 1.

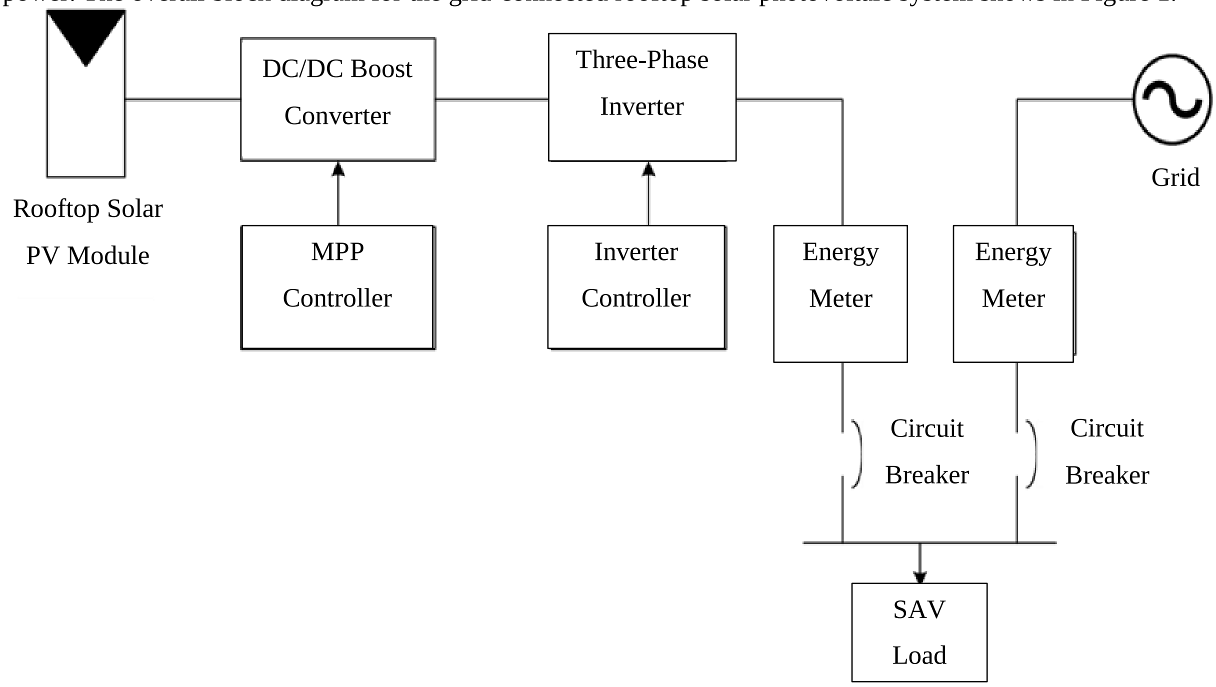

Fig.1. System Block Diagram for Roof-Top Solar PV System

In this paper, a rooftop solar PV system was designed and a corresponding model is implemented. The available roof-top solar PV system for Snake Anti-venom (SAV) building was obtained using PVSol software. Based on these data, the simulation model was developed to observe the output power from the designed system using Matlab/Simulink.

II. DESIGN COMPONENTS FOR THE PROPOSED MODEL SOLAR PHOTOVOLTAIC SYSTEM

A. Solar Photovoltaic Design Software "PVSol"

Designing a solar photovoltaic system needs various components (Photovoltaic module, MPP controller, inverter, etc.) of the solar photovoltaic system to achieve optimal power generation. The resulting photovoltaic system wants to capture the solar irradiance for the selected location. The processes started with simulation software. The primary function of photovoltaic design software is to estimate power and energy output from a specific photovoltaic system. Using PVSol software is a hands-on engineering process for designing photovoltaic systems. The amount of solar radiation and ambient conditions are taken PVSol software to create from Meteonorm software in the selected regions. Building designs transferred to PVSol according to AutoCAD drawings/Google map. The inclination angle and distances between the panels placed according to their design criteria. The amount of electrical energy produced. It calculated in detail with the software for different azimuth angles [6].

B. DC/DC Boost Converter

The boost converter is a DC-DC converter that boosts input voltage based on the formula given:

$$\frac{Vo}{Vi} = \frac{1}{1-D} \tag{1}$$

Where V_o = Output voltage
V_i = Input voltage
D = Duty cycle

It consists of an inductor, an IGBT switch, a fast-switching diode and a capacitor. When IGBT is switched ON, the inductor is connected directly to the input voltage source. When IGBT is switched OFF, the diode is forward-biased. Both the original and the charged inductor connected to the load [3]. Figure 2 shows a circuit diagram for the boost converter [3].

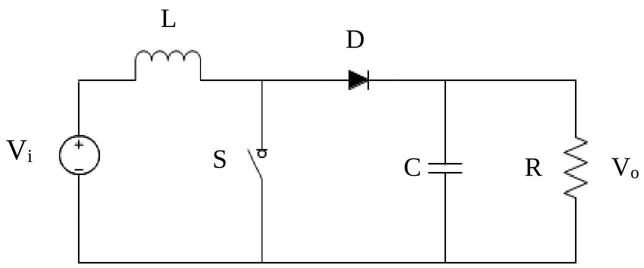

Fig.2. Circuit Diagram for Boost Converter [3]

C. Three-Phase DC/AC Inverter

An inverter converts the electrical energy of direct current form into alternating current. The purpose of a DC-AC inverter is to take natural current power from a solar photovoltaic source and converts it to a three-phase alternating current load. The DC-AC inverters operate on Pulse Width Modulation (PWM) technique [2]. The circuit diagram for a three-phase DC/AC inverter with the controller is shown in Figure 3.

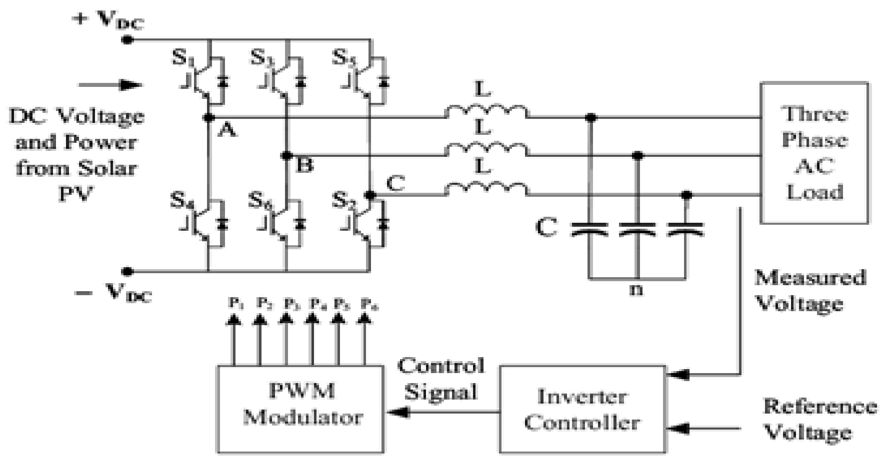

Fig.3. Circuit Diagram for Three Phase DC/AC Inverter with Controller

III. METHODOLOGY

This paper intends to design a photovoltaic system suited to the user's needs and explore possible photovoltaic system solutions. It collects and evaluates meteorological data for the site to determine the available solar resource and environmental conditions and considers available roof surfaces regarding the suitability of installing a photovoltaic system with PVSOL software. After all the processes of PVSol software, the system is designed and simulated from several possible photovoltaic systems using MATLAB/Simulink.

IV. SIMULATION TEST AND RESULTS

The proposed load profile considered the general hourly of per day based on the load usage of the proposed building. The load profile is collected data from the selected building because it can help to design the calculation of rooftop solar photovoltaic systems. The load power of the proposed building shows in Figure 4. Depending on the load profile, the values of the components are calculated for the system.

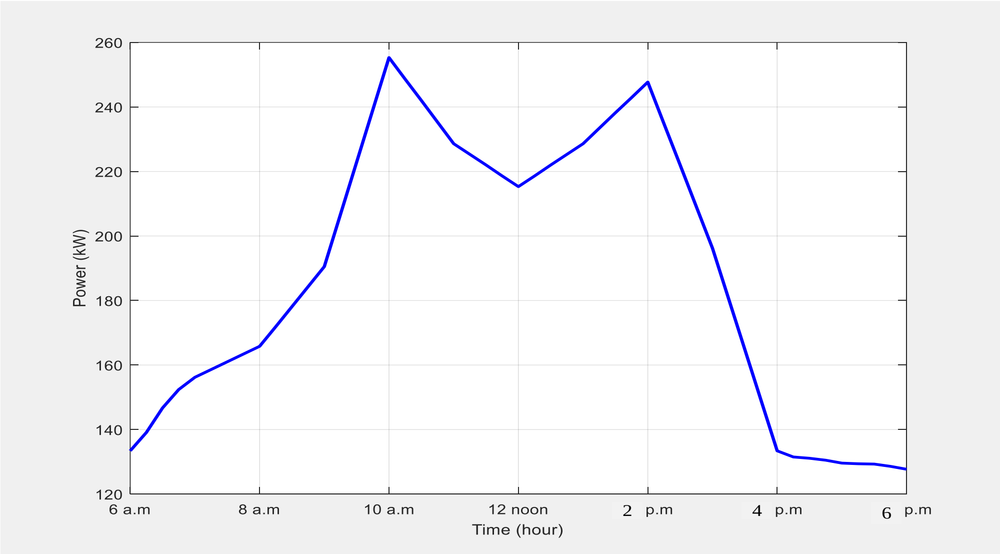

Fig.4. Load Power of Proposed Building

This energy considered for 12 hours. Therefore, the changes range of energy results of the system is from 6 AM to 6 PM, and the other times are in zero condition. The temperature is constant at 25℃. The maximum power demand of the SAV building is about 260 kW from data collection. Figure 5 shows the load energy of the proposed building.

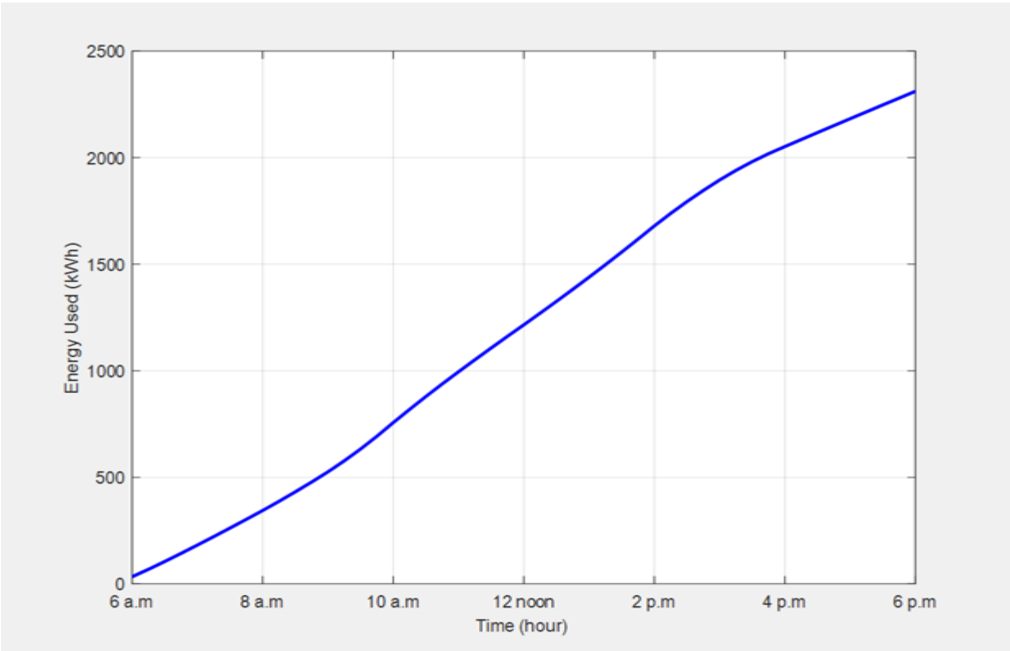

Fig.5. Load Energy of Proposed Building

Figure 6 shows the project data from PVSOL software. The number of photovoltaic modules is 625 among them 14 inverters are used. The output power from photovoltaic modules is 196.88 kW. From the results of PVSOL software, there are two types of inverter: Inverter Type I, each including 12 modules, two lines and 21 modules, one line composed with nine inverters and Inverter Type II, each including 12 modules, two strings and 20 modules, one string contained with five inverters. Figure 7 shows the installation diagram from the proposed system of PVSol software.

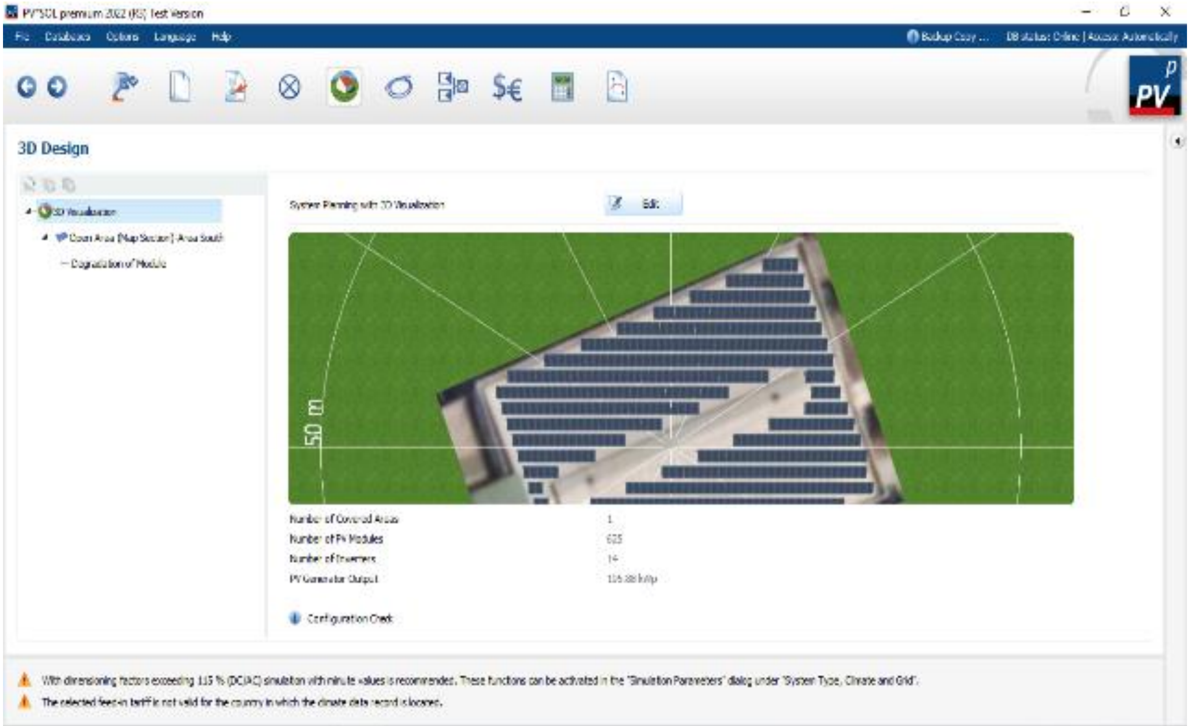

Fig.6. Main Parameter for Designed Photovoltaic System

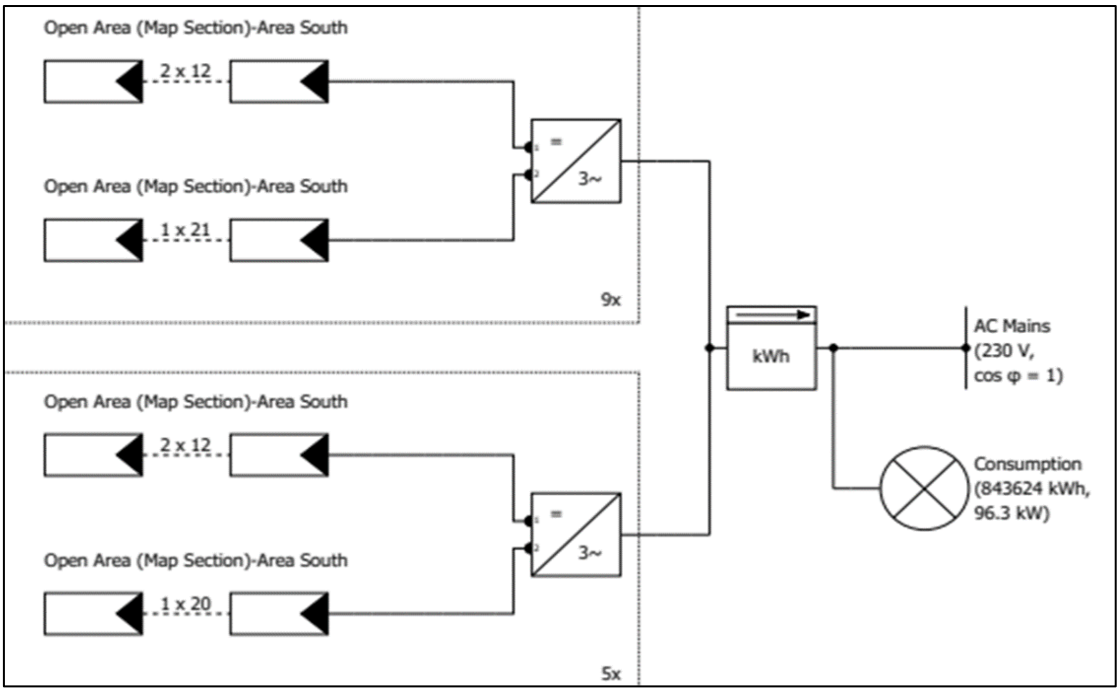

Fig.7. Installation Diagram from Proposed System

The power in 12 modules, two strings, is 7561.73 W and the power in 21 modules, one line, is 6616.5 W. The total capacity for inverter type I is 14178.2 W. The inductance value of 5.85 mH and the capacitance value of 14.2 µF are the values of the LC filter in inverter type I. Figure 8 shows the simulation model for inverter type I. Figure 9 shows the voltage, current and power outputs of inverter type I.

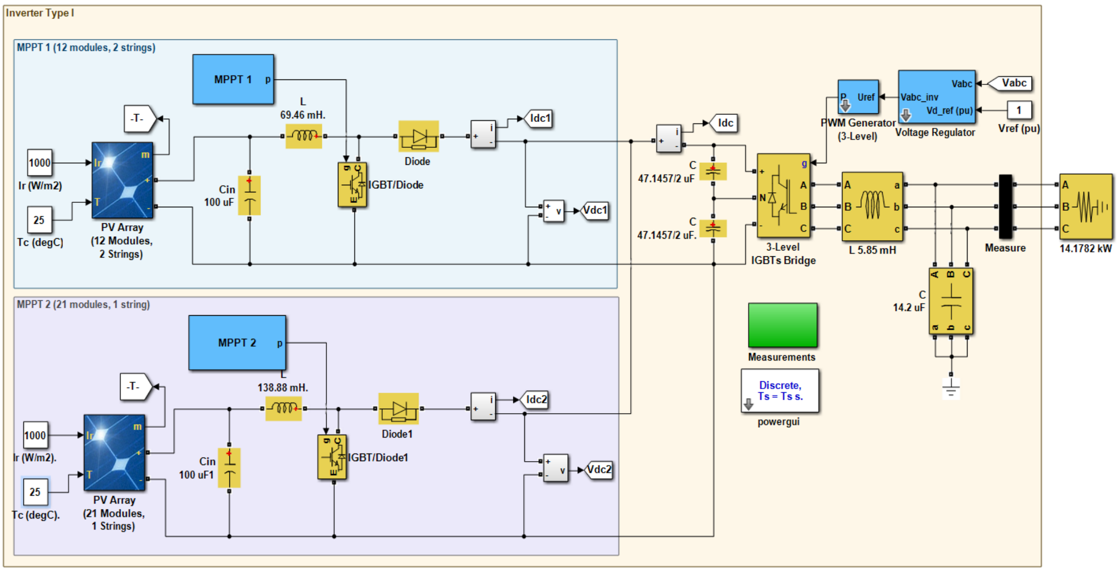

Fig.8. Simulation Model for Inverter Type I

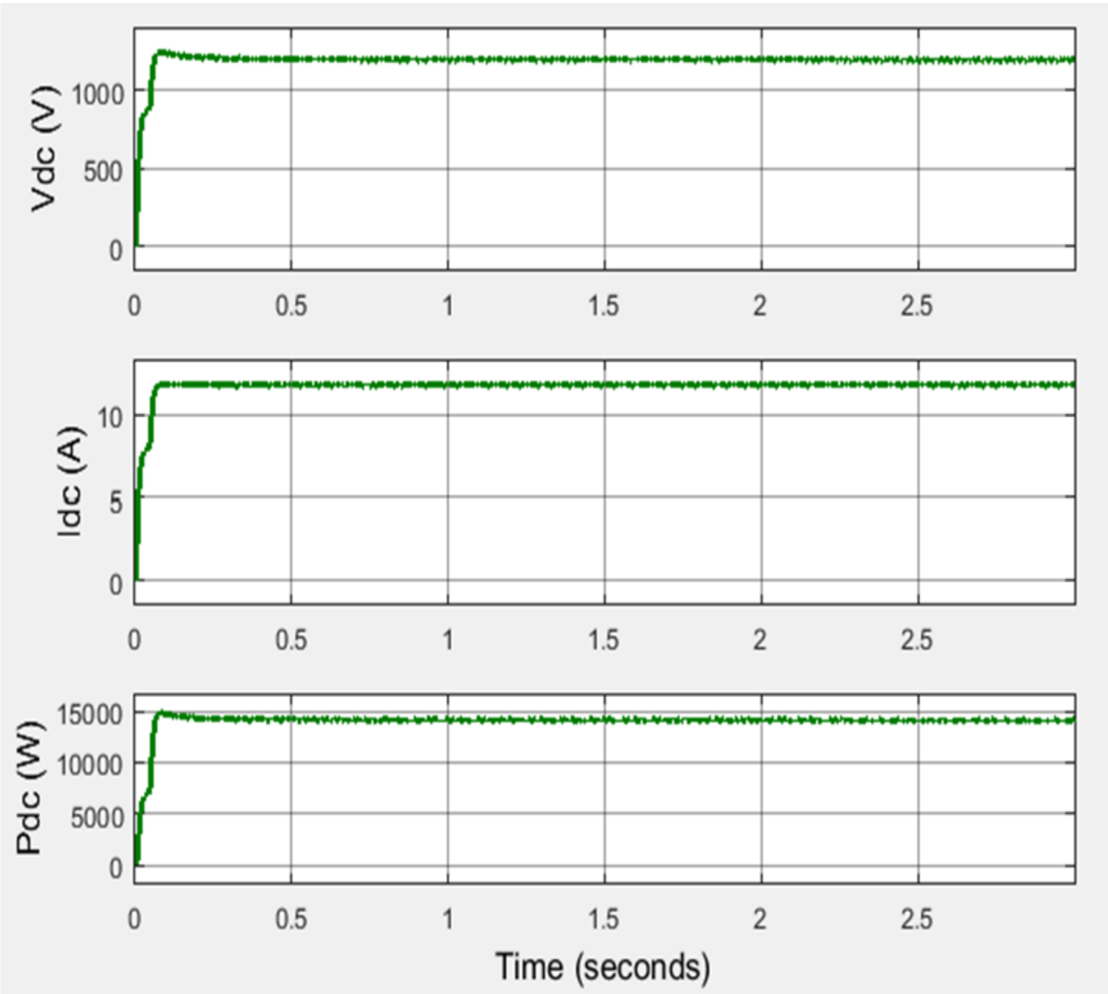

Fig.9. Voltage, Current and Power Outputs of Inverter Type I

Figure 10 shows the simulation model for inverter type II. The power in 12 modules, two strings, is 7561.73 W and the power in 20 modules, one line, is 6301.44 W. The total capacity for inverter type II is 13863.14 W. The inductance value of 5.98 mH and the capacitance value of 13.9 μF are the values of the LC filter in inverter type II. Figure 11 shows the result of voltage, current and power outputs of inverter type II.

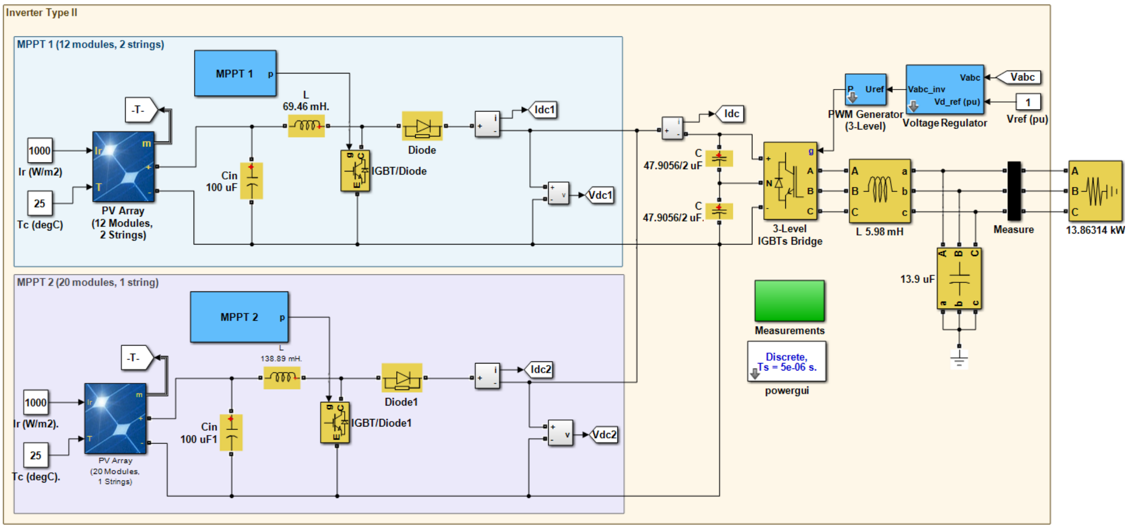

Fig.10. Simulation Model for Inverter Type II

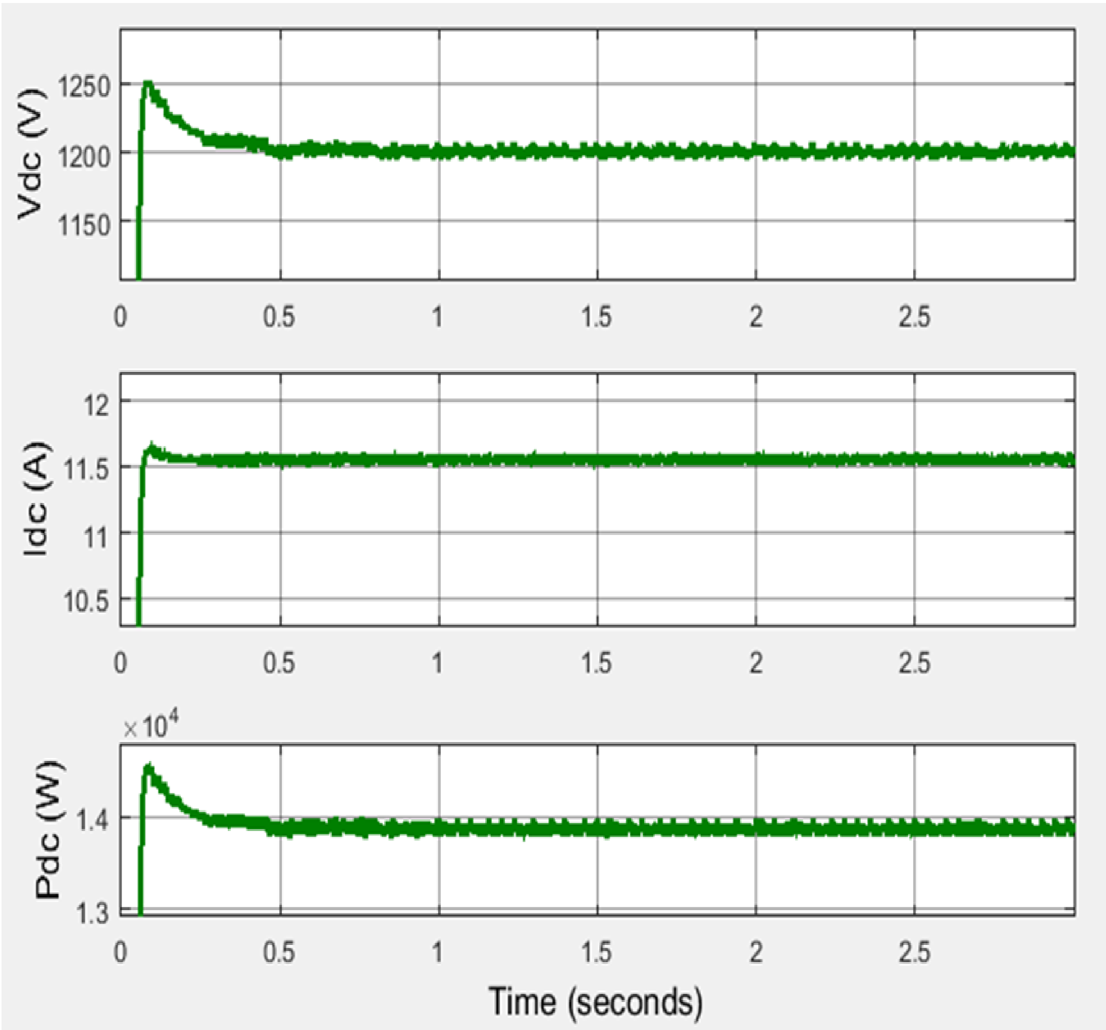

Fig.11. Voltage, Current and Power outputs of Inverter Type II

After each result, the 14 inverters were built as a complete inverter system of a rooftop solar photovoltaic system to get power for the load profile. The overall output power from the solar photovoltaic system is approximately 196.8 kW. Figure 12 shows the simulation model for the complete rooftop solar photovoltaic system.

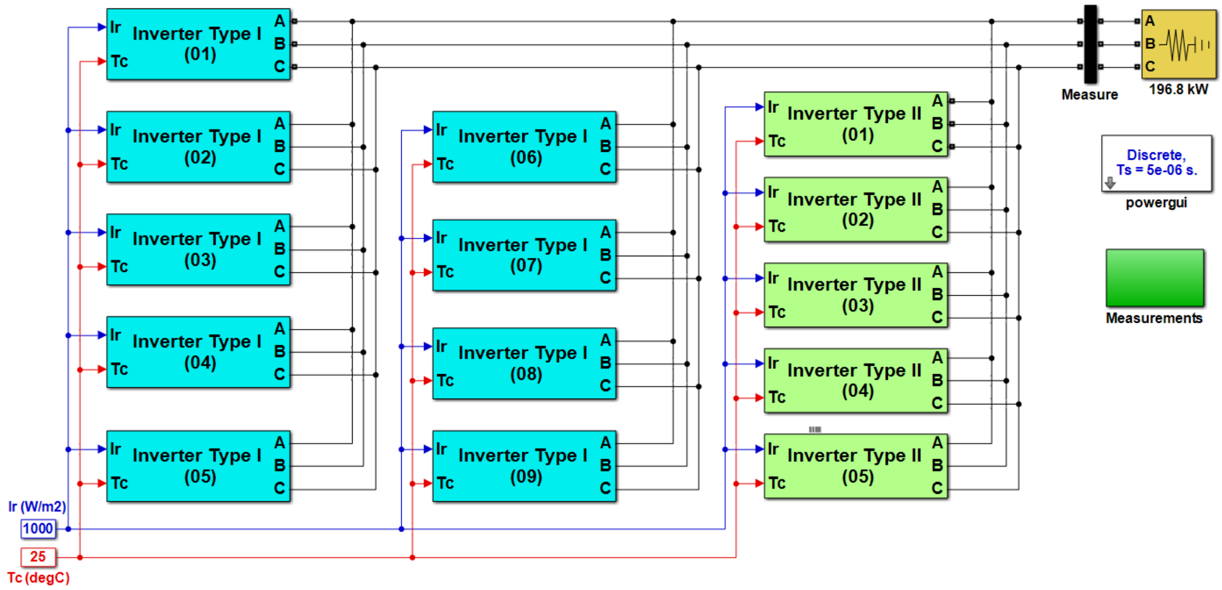

Fig.12. Simulation Model for Complete Roof-top Solar Photovoltaic System

The voltage and current output from the roof-top solar PV system are shown in figure 13. The power output from the rooftop solar photovoltaic system shows in figure 14.

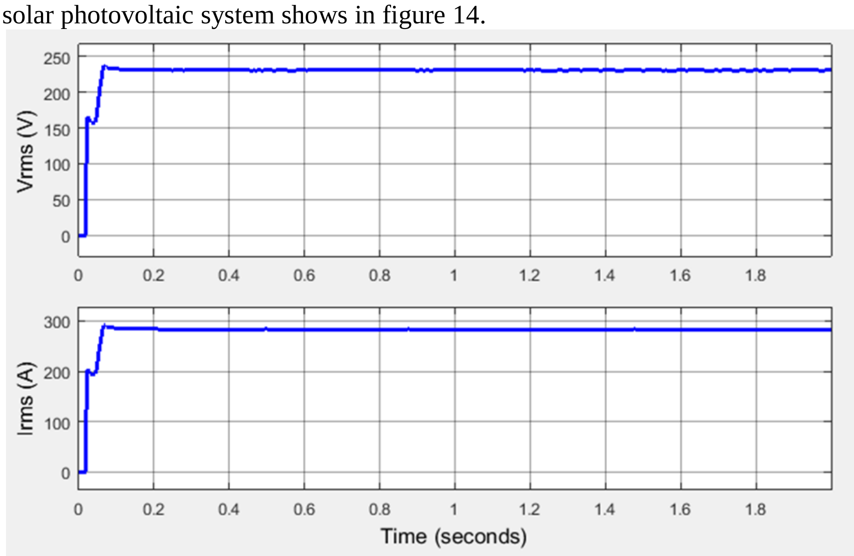

Fig.13. Voltage and Current Output from Roof-top Solar PV System

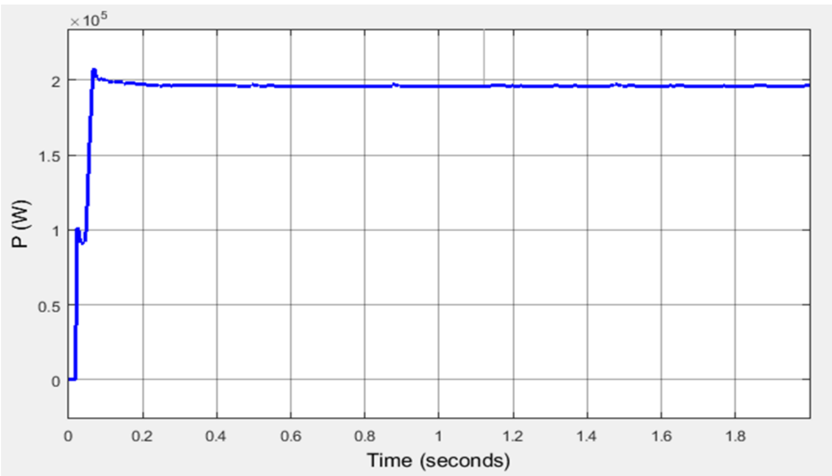

Fig.14. Power Output from Roof-top Solar Photovoltaic System

V. Conclusion

In this paper, the design and modelling of rooftop solar photovoltaic systems are presented for the industrial building. For detailed study and practical application, the SAV building of Myanmar Pharmaceutical Factory was selected as a case study. The simulations were carried out for DC/DC boost converter with MPPT controller, three-phase DC/AC inverter and results for the complete rooftop solar photovoltaic system. From the simulation results, the maximum power from PVsol is 196.88 kW. In the simulation of the Simulink model, the power output is about 196.1 kW with standard operation conditions (i.e., 1000 W/m^2 irradiance and 25°C temperature), which is nearly the same as the PVSol result.

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