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TYPICAL PHOTOVOLTAIC SYSTEM FOR A COMMERCIAL BUILDING

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ABSTRACT: This paper covers the design and installation of an 11 peak kilowatt (kWp) grid-connected photovoltaic system on the roof of the new facilities at the Florida Solar Energy Center (FSEC[7]). The main objectives of this work are to demonstrate the application of photovoltaics (PV) as a demand-side management option for meeting peak commercial electric loads and provide a typical PV array and system design for commercial buildings. The PV array consists of 48 ASE America=s EFG ribbon silicon modules and is interfaced with three Omnion 4kW power conditioners. The complete array and system electrical design and installation were performed by FSEC staff and comply with 1996 National Electric Code. The installed PV system is instrumented for detailed system performance data collection to assess the efficacy of the PV system generation profile in meeting the building air-conditioning load profile, which is a major contributor to total peak electric loads in Florida.
Key words: Small Grid-connected PV Systems - 1: PV Array - 2: Demand-Side - 3

1. INTRODUCTION

The primary objectives of this work are to showcase PV technology at FSEC, demonstrate the contribution of photovoltaics to demand-side management of commercial electric loads, and also to provide a typical array and system design for commercial buildings.

This paper describes the design and installation of an 11 kWp grid-connected PV system on the new FSEC laboratory building. The FSEC laboratory is a manufactured commercial building built by American Building Suppliers in Alabama. The laboratory building has a metal structural support system that has been constructed to allow for an additional roof loading. The building consists of a low-bay and a high-bay section. The PV array is installed on a flat roof of the low-bay section for high visibility. The array is installed at a 15° tilt for better utilization of the roof space, but more importantly to increase the summertime PV generation to meet higher air conditioning load demand. The better roof utilization is achieved through installing the array in one plane and thereby avoiding the extra space needed, otherwise, to minimize row to row shading.

2. PHOTOVOLTAIC ARRAY

2.1 PV Modules and Configuration

The PV array consists of 48 ASE America=s EFG (Edge-defined, Film-fed Grown) ribbon silicon modules. The PV modules include 32 EVA encapsulated 238* Watt modules (ASE-260-GP-50) and 16 non-EVA encapsulated 261* Watt modules (ASE-300-DGF/50) to provide side-by-side comparison of their performance, degradation, and discoloration in identical, hot, humid and salty environments of coastal Florida. Each module is rated at maximum power voltage of 45.5 volts. The array is installed in six rows (east to west), with each row having eight modules connected in series. The two center rows have the non-EVA encapsulated modules and are about 34 feet long. The other rows have the EVA encapsulated modules and are about 32 feet long. The non-EVA encapsulated modules are slightly larger and have 10 percent higher power output than the EVA encapsulated modules.

2.2 PV Array Mechanical Design

The PV array mechanical design was done by a local architecture and engineering (A&E) firm of Healey and Associates. The array mechanical design meets the national and local building codes, including the requirement of 120 mph wind loads in accordance with the Standard Building Code (SBCCI-91). Figure 1 shows the important details of the array mechanical design.

The array support structure utilized a lightweight ?braced frame@ structural system spanning the standing seam metal roof and attaching to the girders supporting the building. The structural frame, which is totally independent of the roof deck, connects to the existing structural support system by means of column extensions (stub-ups) between the building=s girders and existing metal roof. The attachment to the PV array support structure is covered with a rubberized boot to prevent water intrusion.

2.3 PV Array Electrical Design

The PV array electrical design was performed by FSEC staff and it complies with the 1996 National Electric Code (NEC 96). The array electrical design also includes fault

*Rating at standard operating condition (SOC) of 1000 W/m^2 irradiance, 45°C module temperature and airmass 1.5 spectral distribution.

protection and fault tolerance features for improved safety and reliability. These features include blocking diodes to avoid reverse current flow, fuses for current limitation, silicon-oxide varistors for surge suppression and means for ground fault detection and interruption (in power conditioners). Each row of eight modules is a bipolar source circuit with a nominal dc voltage of $\pm$182 volts. The PV array is electrically divided in three subarrays and each subarray consists of two parallel source circuits. Two of the three subarrays have a nominal rating of 3.55 kWp each and the third subarray has a nominal rating of 3.9 kWp (with the assumed total losses of 7 percent due to wiring, mismatch and soiling). Figure 2 illustrates the electrical schematic of the PV system, including the array.

3. POWER CONDITIONERS AND GRID INTERCONNECTIONS

Each of the three subarrays is interfaced with an Omnion Power Engineering Corporation's 4kW single-phase power conditioners (series 2400). The ac output of the three single-phase Omnion power conditioners is arranged in a three-phase configuration to interconnect to the local utility's electric grid on a three phase 208/120 volt transformer (300kVA 480 volt delta to 208/120 volt wye).

The approval process by local utility for grid interconnections was very tedious, involving long delays and major expenses. More than a year was taken to interconnect the PV system to grid from the time of request for such interconnections. The utility required equipment costing $7,000 for interconnection of the PV system and also $1,884 for testing to determine the suitability of the interconnection equipment. In view of the protection and safety features already employed in the Omnion power conditioners, the inclusion of the utility required equipment is redundant. In addition, the utility also required one million dollar liability insurance for the PV system, which cost $5,715/year.

4. PV SYSTEM INSTALLATION AND CHECK-OUT

The PV array support structure was installed on the roof of the low-bay laboratory by a local contractor, Space Coast General Contractors. The galvanized iron support structure was first installed and it was welded in-place at the designated interfaces, followed by the application of epoxy paint to minimize corrosion. The PV modules on the support structure were installed by FSEC staff. All the equipment (including power conditioners), balance-of-system components (blocking diodes, silicon-oxide surge arresters, fused disconnects, disconnect switches) and electrical wiring were also installed by FSEC staff. Figure 3 shows the installed PV array on the roof.

Prior to interfacing the three subarrays to the power conditioners, the checkout of the PV array was performed. For this purpose all the module interconnect wiring, source circuit wiring, grounding wires, junction boxes and balance-of-system components connections were visually checked.

Next, the open circuit voltage and short circuit current of each half of each source circuit were checked, and the

Figure 3: Installed PV Array.

current-voltage (I-V) curves of each source circuit individually and the three subarrays were recorded to assure the values were within the acceptable range. Finally a resistive load of 4kW, 40 Ω was connected across each subarray successively to verify each subarray's safe operation for a minimum of one hour. After conducting successful array checkout, each subarray was interfaced with an Omnion 4kW power conditioner, while the subarray dc disconnects had been turned off.

The interconnection to the grid (wye secondary of 300kVA transformer) were made at the three-phase output of the power conditioners, while the utility power had been turned off and the power conditioner ac disconnects were also turned off. Both dc and ac disconnects for each subarray were turned on to energize each power conditioner successively and their safe and proper operation was verified.

5. SUMMARY

The design and installation details of an 11kWp grid-connected PV system have been presented. The PV system illustrates a typical mechanical and electrical design for a commercial building. The PV array is installed on the flat roof of a manufactured building used as the FSEC laboratory. At this time the work is in progress to assess the contribution of the PV system generation profile to meeting the building electric load demand.

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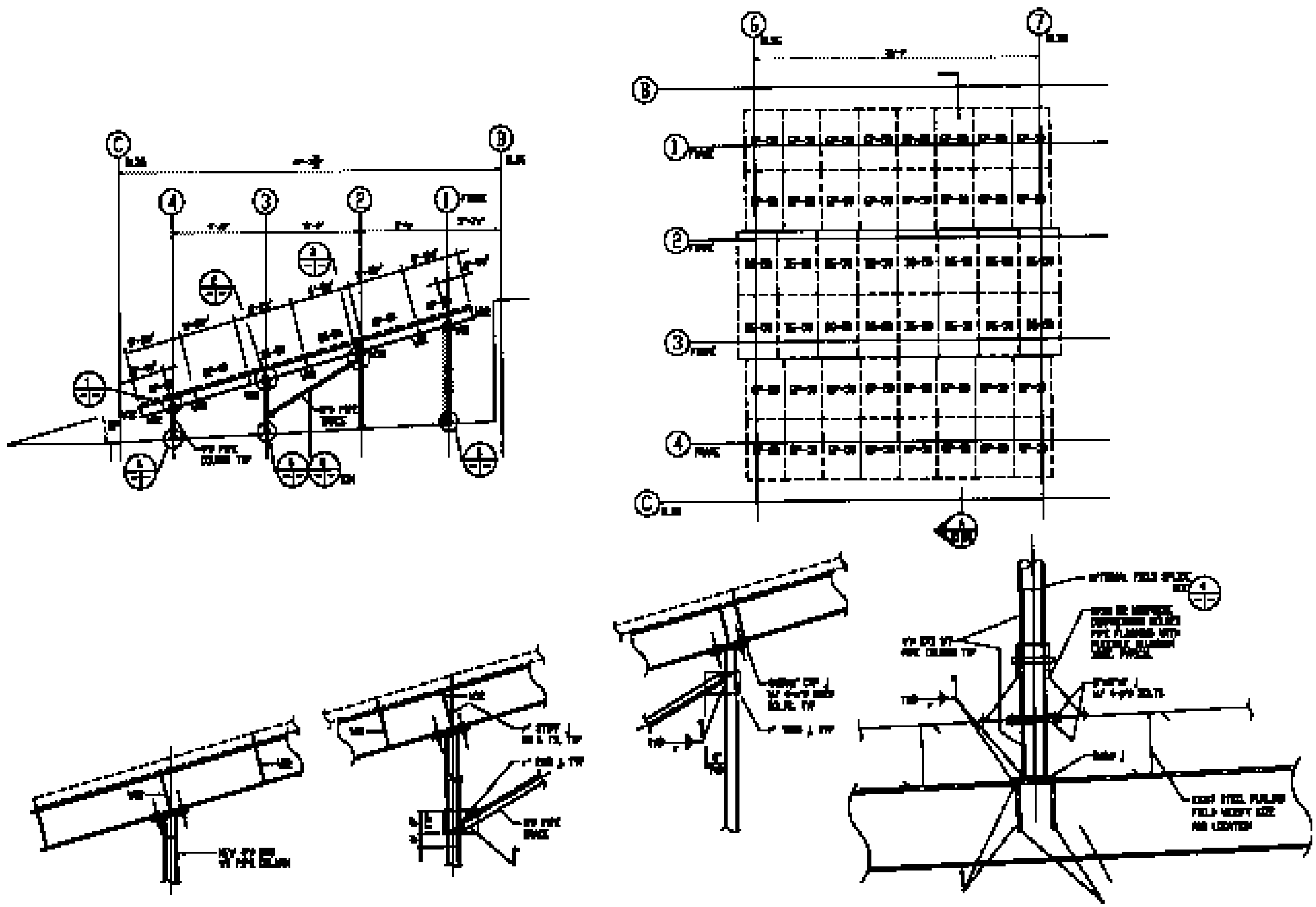

Section Detail 1. Section Detail 2. Section Detail 3. Section Detail 5.

Figure 1. FSEC PV Array and Support Structure

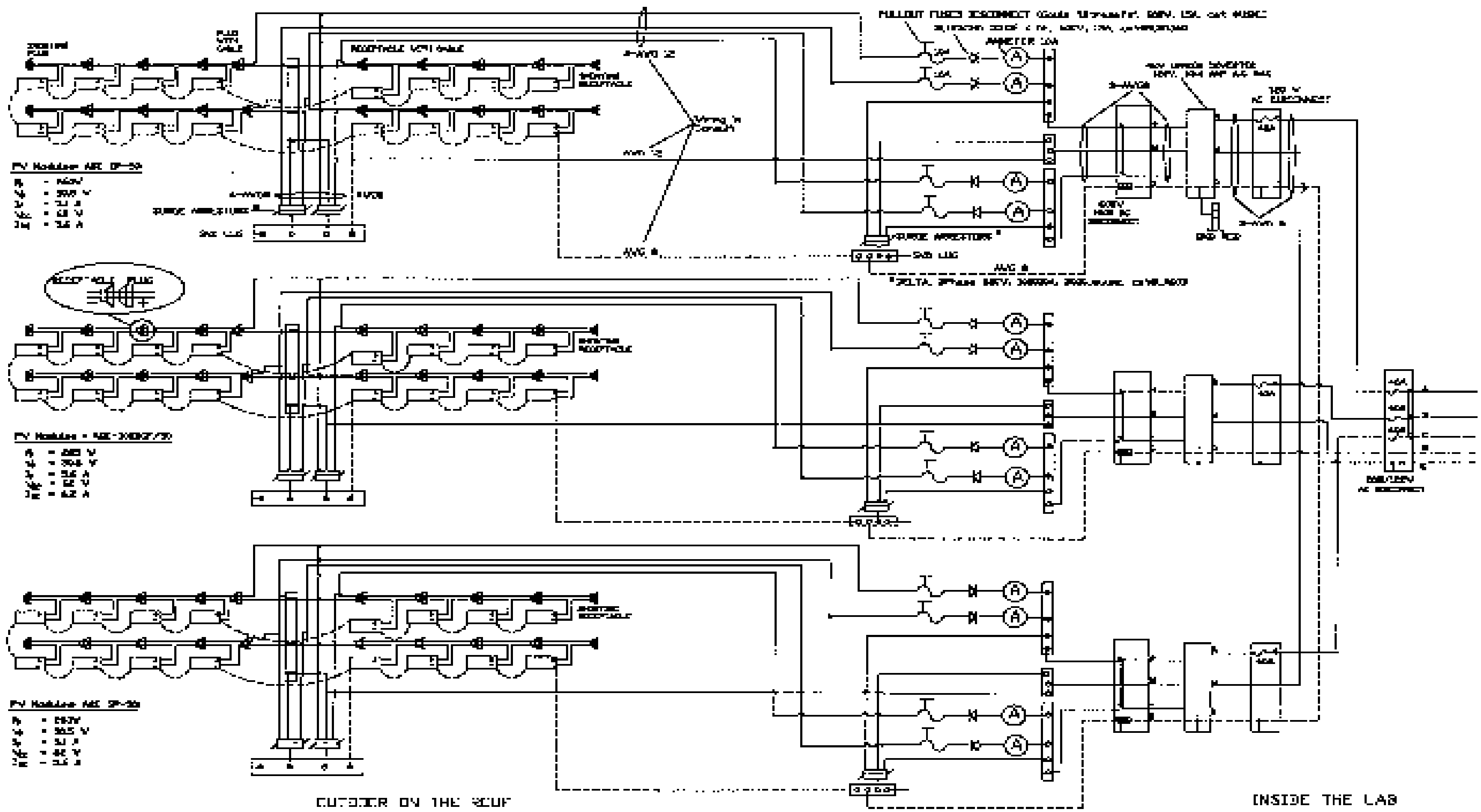

Figure 2. Electrical Schematic of the FSEC PV System