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Installation of 3.8 Mw Solar Photovoltaic Power Plants in Bompai Industrial Layout, Kano Nigeria

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Abstract—This paper discussed on the installation of a solar photovoltaic power plant that would meet the energy requirement of two industries in Bompai industrial area of Kano, Nigeria. The two industries are Ammasco Int. Ltd and Holborn Nig. Ltd. The energy demand of these two industries has been estimated to be 3.44 MW and the design of solar PV power plant of 3.8 MW has been proposed, which requires about 27.65 acres of land area. Due to inadequate availability of space within the vicinity of the industries, roof mounted option is considered for the installation of the solar PV power plant and the simple payback period is 5.27 years.

***Index Terms*— Key word: Solar PV, Inverter, Battery sizing, Energy, Site selection.**

I. INTRODUCTION

Bompai industrial area of Kano state has over 60 industries and most of their products are lubricants, water tanks, household plastics, Sacks, Grains milling, Agricultural products and textile products to mention are few. These industries use inductive loads which consume more power. Electricity is also needed for lighting, fans and air conditioners. It was reported that over 100 industries in Kano state have collapsed due to lack of constant electricity. Today, most of the industries in Kano run on backup diesel generators as an alternative energy source. The average energy demand of the Bompai industrial area is 30 MW and it varies monthly. These days getting a continuous and uninterrupted supply of energy has become the largest problem for the industries, especially in Kano state, where production gets affected by regular energy shortages. The backup generators have a very high operation cost and are not clean source of energy either. Therefore, there is great need for a sustainable and clean source of energy; solar energy is the largest existing renewable energy source which can meet the energy demand of the Bompai industrial area.

In this project, a 3.8 MW onsite solar photovoltaic power plant was designed along with the land requirement and economic analysis for 2 industries in Bompai industrial area, which are Ammasco Int. Ltd and Holborn Nig. Ltd. These two industries are considered as a case study for the design.

II. SITE SELECTION

For PV solar panels it is important to avoid any shading that would reduce energy output. Again, for PV systems the best option is roof mounted installation. Most of roofs are high enough to surpass any vegetation and other shadings on site in height. Of course the ability of a building to endure all PV mounted on it should be investigated during the pre-planning process. Another factor that affects energy output from PV panels is orientation. Solar panels should always face true south if you are in the northern hemisphere, or true north if you are in the southern hemisphere [1]. For Kano, PV panels are oriented south to maximize energy generation. The tilt angle of PV is important as well. For Kano area the tilt angle is around 35 degrees.

III. LOAD DETERMINATION

A questionnaire based survey was conducted from February to March, 2015 for energy demand estimation in Bompai industrial area, Kano. After the primary survey the questionnaire was modified and used. The questionnaire comprised of the adequate availability of space within the vicinity for solar power, peak load demand, minimum load demand, energy requirement per day for each individual industry, number of different type of machines, their energy consumption and duration of operation, etc. The estimated energy requirement for the 2 industries is summarised in table I below.

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Table I. Energy requirement for two industries in Kano

S/N	Industry	Peak Load demand (KVA)	Energy requirement per day (KWH)
1	Ammasco International Ltd.	1,800	14,298
2	Holborn Nigeria Ltd	2,500	19,000
	Total	4,300	33,298

IV. DESIGN OF SOLAR PHOTOVOLTAIC POWER PLANT

The estimated peak load demand for the two industries was 3.44 MW in the month of February 2015 and considering an expected increase in future, a 3.8 MW solar PV power plant is considered for the two industries. The design of solar photovoltaic power plant (Fig. 1) consists of PV module sizing, inverter sizing, battery sizing and module circuit design. Design methodology and technical conditions of the PV power plant are discussed in this section.

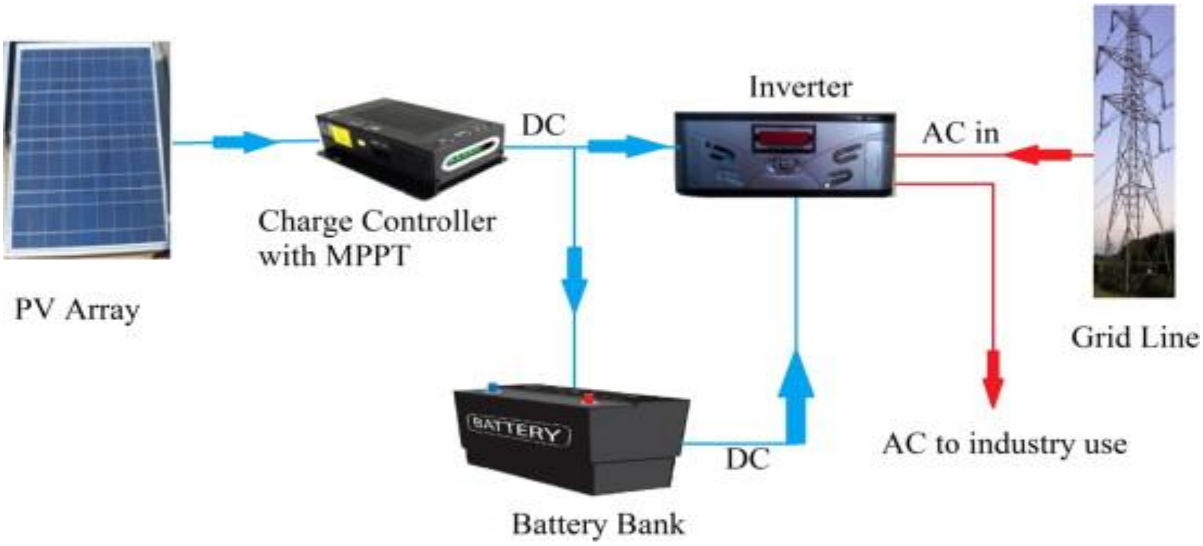

Fig.1. On site solar PV power plant [1]

A. Panel Generating Factor

Panel generation factor (PGF) is a key element in the size determination of solar PV cells on the basis of total watt peak rating and then for estimating the number of panels required for a particular solar PV plant, which varies with the solar intensity and sunshine period of the site [2].

$$\text{Panel generation factor} = \frac{\text{Solar irradiance} \times \text{sunshine hours}}{\text{Standard test conditions irradiance}} = \frac{617 \times 8.38}{1000} = 5.17$$

B. Energy Required from PV Modules

Energy required from PV modules can be calculated by multiplying peak energy requirement in kW h/day multiply by 1.3 (the energy lost in the system) to get the total kW h/day which must be provided by the panels.

Peak energy requirement = 33,298 KWh/day

Energy lost in the solar PV system=30% [2]

Energy required from PV modules = 33,298 KWh/day ×1.3 = 43,287.4 KWh/day

C. Total Watt Peak Rating For PV Modules

Total Watt peak rating is calculated using the energy required to be produced from the solar PV modules and the panel generation factor [2].

$$\text{Total watt peak rating for modules} = \frac{\text{Energy required from PV modules}}{\text{Panel generation factor}}$$

$$\text{Total watt peak rating for modules} = \frac{43{,}287.4}{5.17} = 8{,}372.8 \text{ KW}$$

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D. PV Modules

A Polycrystalline PV module with the following specifications is selected for this power project:
Maximum Power: 240W
Maximum Voltage (Vmp): 30.3V
Maximum Current (Imp): 7.92A
Open Circuit Voltage (Voc): 37.1V
Short Circuit Current (Isc): 8.88A
Maximum System Voltage: 1000 VDC
Dimension: 1.653m × 0.995m × 0.045m
At STC: air mass 1.5, irradiance = $1000W/m^2$, cell temperature = 25^0C

E. Number of PV Modules Required

Total numbers of PV modules required in the power plant is calculated using the total watt peak rating required and the PV module peak rated output [2].

$$\text{Number of PV modules required} = \frac{\text{Total watt peak rating}}{\text{PV module peak rated power}}$$

$$\text{Number of PV modules required} = \frac{8372.8\ X\ 1000}{240} = 34,886.667 \approx 34,887 \text{ modules}$$

F. Inverter Sizing

Size of the inverter used in PV power plant depends on the total peak watts requirement. Total energy required in the two industries was 3.8 MW. The inverter must be large so as to handle the total peak watt requirement of the industries at any time. The inverter size should be 25 - 30% bigger [3] than the total wattage of the appliances and machines. Inverter size = 3.8 MW×1.3 = 4.94 MW.
SatCon Power Gate Plus 500 kW 480/3 Inverter [1] is considered for the PV power plant which has an inbuilt maximum power point tracking (MPPT) system.
Number of inverters required = Inverter size/rating of an inverter = 9.88 ≈ 10
Inverter wattage = 10×500 = 5000KW = 5MW
MPPT is a fully electronic system that varies the electrical operating point of the modules so that the modules are able to carry maximum available power. MPPT is not a mechanical tracking system that "physically moves" the modules to make them point straight in the direction of the sun. Additional power harvested from the modules is then made available as increased current.

G. Battery Sizing

Total battery watt hours used per day = 33.298×10^6 Wh/day
Battery loss = 15%
Depth of discharge for battery = 40%
Nominal battery voltage = 96V [2]

$$\text{Battery Capacity (Ah)} = \frac{\text{Total watt hours per day by appliances} \times \text{Days of autonomy}}{0.85 \times 0.6 \times \text{nominal battery voltage}}$$

$$\text{Battery Capacity (Ah)} = \frac{33,298,000 \times 1}{0.85 \times 0.6 \times 96} = 680,106.21 \text{ Ah}$$

H. PV Module Circuit

Maximum open circuit voltage = $1000V_{dc}$
Open circuit voltage (VOC) of each PV module = $37.1V_{dc}$
Number of modules to be connected in series = (1000/37.1) = 26.95 ≈ 27
Maximum power voltage (Vmp) of each PV module= 30.3 V_{dc}
Maximum power voltage (Vmp) at inverter input= 27 × 30.3 = 818.1 V_{dc}
Total number of PV arrays to be used for producing 818.1 V_{dc}= 34,887/27 ≈ 1,293 arrays

I. Land required

Dimension of one PV module = 1.653 m × 0.995 m × 0.045 m

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Number of modules in an array connected in series = 27
Number of PV arrays = 1,293
Length of solar field = total length of module + total pitch distance between arrays
Where pitch distance between two arrays = 1.57m [5]
Length of solar field = (1.653m × 1293) + (1.57m × 1292) = 4165.769m
Width of solar field = total width of module in series = (0.995m × 27) = 26.865m
Land required for PV field = Length of solar field × width of solar field
Land required for PV field = (4165.769m × 26.865m) = 111,913.38m2 = 27.65 acres
Note:[1 acre = 4047 m2]

V. ECONOMIC

The use of PV systems requires an initial capital investment, but thereafter the running costs are very low [6]. The purchase price of a PV system typically contains four main costs: Module and Inverter cost, Battery Bank cost, Transport and installation costs, Project management costs, design and engineering. The initial capital investment cost of this project is $9,200,000 and saves $1,747,328.6 per year. For the solar PV power plant internal rate of (IRR) is 18.99%, net present value (NPV) at 10% discount rate is $1,536,635.3 and simple payback period (SPP) is 5.27 years.

VI. ENVIRONMENTAL ANALYSIS

PV energy modules do not cause any significant environmental impact. They do not have any moving part and generate no noise. Similarly, PV panels are generally located on flat surfaces, so the visual impact and impact for birds' life is not very significant. The major environmental issue of PV technology is land use. For example each kilowatt of power capacity takes about 7.5m^2 of surface [7]. When PV panels are roof mounted, they do not take any useful area, however for utility scale ground mounted PV plants, land use is a significant problem.

VII. CONCLUSION

Feasibility study has been carried out to install a 3.8 MW solar photovoltaic power plant that would meet the electricity needed by the two industries in Bompai industrial area of Kano state, considering onsite option. For this power generation, a total of 34,887 PV modules are required with 27 modules in each row. Ten inverters with MPPT controller of 5 MW capacity and battery bank of 680,106.21 Ah are also required to supply the power and the total land area required is 27.65 acres.

In the onsite PV power plant, PV modules are placed on the roof top of the industries and modules are connected to a centralized battery bank and inverter. Finally, financial performance indicators (internal rate of return - IRR, net present value - NPV and simple payback periods - SPP) are analysed. Financial analysis shows that the PV power generation option is better and feasible.

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