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Performance Evaluation of An On Grid 100 MW Quaid-E-Azam Solar Power Bahawalpur

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Abstract
In today's life renewable energy generation is a desperate need for the sake of independence from resource limitation and elimination of harmful products e.g. CO2. Pakistan has great potential for solar power due to its geographical location. So grid connected photovoltaic systems are becoming increasingly important. This paper presents the performance analysis of 100 MWp on grid solar power plant Bahawalpur. System was observed from Jan 2016 to Jan 2017. Day to day solar irradiance, wind speed, site temperature, relative humidity and air pressure are measured. The QASP plant operates at 18.28% capacity with an annual production of 160.1 GWh of energy during 1st year. Location, solar irradiation, shading, weather conditions, layout, equipment quality, system design, operation and maintenance affect the solar power generation. So the annual degradation factor is 0.7%. A decrease in performance ratio was seen due to increase in temperature and conversion losses.

Keywords: Renewable energy; solar power; Quaid-e-azam solar power; Ambient temperature; Photovoltaic;

I. INTRODUCTION

From most recent couple of years Pakistan is facing extreme energy crises. So it is our divergent need to wind up the gap between the power supply and demand. Punjab territory, being the biggest energy buyer of Pakistan is severely influenced by these energy crices. So GOVT of Punjab chose to create power through sustainable power source assets. Among all the sustainable power source assets, solar energy is the most conspicuous source. Quaid-E-Azam solar power (QASP) is the main imitative towards this point of reference. QASP park is located in the cholistan desert, 20KM away in southeast of Bahawalpur . It is the largest solar power plant of Pakistan with the capacity of 100 MWp in the 1st phase, 300 MW in the 2nd phase and 600 MWp in the 3rd phase [1]. Total globally installed capacity of solar energy was 15 GW, 28 GW and 32 GW in 2008, 2009 and 2010 respectively [2]. At the end of 2016 this amount was 302 GW so the trend of solar energy is increasing rapidly. According to B Kumar, the largest Photovoltaic power generating countries are Germany, Italy, china, japan, USA and UK[3].

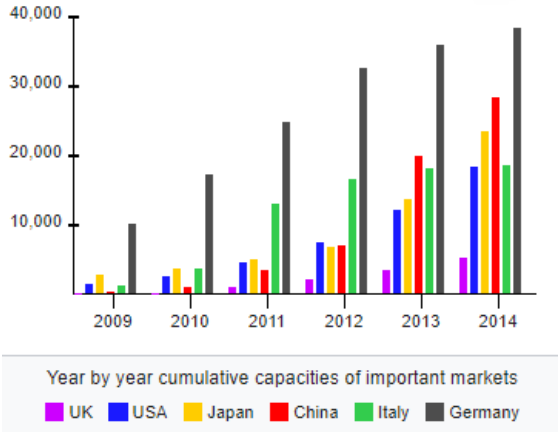

Fig. 1. Yearly PV capacity of leading countries [3]

PV module yield maximum energy during maximum sunshine hour, higher irradiance, lower temperature and high breeze. The major degradation factors for pv modules are humidity and dust[4],[5]. So there should be a proper way to minimize these effects. To maintain the power quality and efficiency of pv modules, they should be cleaned by fresh water and remarkable sorts of surfactants [6].

This paper focus on the evaluation of performance of already installed on grid 100 MWp solar power project in Bahawalpur. To advance the efficiency and cost effectiveness of next generation photovoltaic systems, it is important to analyze and evaluate the existing PV systems. The performance of solar PV system depends upon solar irradiance, ambient temperature and thermal properties of photovoltaic panels.

II. DESCRIPTION OF PHOTOVOLTAIC SYSTEM INSTALLED AT QASP SITE BAHAWALPUR

On May 05,2015, the largest grid connected solar power plant was inaugurated ant it started its operation on July 15,2015. Its installed capacity is 100 MWp DC at Standard test Conditions STC. It is located in cholistan desert, 20 KM away from Bahawalpur in Southeast. The daily average irradiance value in Pakistan is 5.3 KWh/m^2[7]. The average yearly solar irradiance is 19MJ/m2/yr. The total global horizontal irradiance for QASP site Bahawalpur is 1896.5kWh/m^2 and average ambient temperature is 25.8 ^{0}C.

Table 1. Total irradiance and average ambient temperature of QASP site 2016

2016		
Month	**Global Horizental Irradiance (kWh/m2)**	**Average Ambient Temperature(°C)**
Jan-16	87.13	11.5
Feb-16	135.17	15.6
Mar-16	152.36	22.0
Apr-16	178.13	29.0
May-16	213.43	35.2
Jun-16	203.78	36.4
Jul-16	198.12	34.3
Aug-16	171.81	31.9
Sep-16	185.66	31.3
Oct-16	158.01	27.1
Nov-16	114.67	19.7
Dec-16	98.23	15.4
Total Irradiance and Ambient Temp.	1896.5	25.8

A. Site Details

QASP Photovoltaic system is installed in Bahawalpur. General specifications of the park are mentioned below.

Table 2. General site parameters

Area covered by park	500 acre
Longitude and latitude of site	71.67^0 E , 29.41^0 N
Maximum ambient temperature	50^{0}C
Average ambient temperature	25.8^{0}C
Maximum wind speed	74km/h

Fig. 2. QASP PV system site

B. Solar Panel/ PV Modules

Solar modules introduced at QASP site are fabricated by JA solar, China. QASP plant has the facility to test the evaluations of PV modules at Standard Test Conditions (STC), 1000 W/m2 irradiance, Air Mass (A.M) 1.5 and 25^{o}C temperature. All the photovoltaic system related instruments are given by PVLAB Germany[8]. Experimental outcomes and nameplate evaluations are demonstrated as follows.

Table 3. Nameplate readings VS measured results of Photovoltaic panels

No.	Parameter Name	Nameplate Reading	Measured Results
1.	Maximum Power (P_{max}).	255 W.	262.8250 W
2.	V_{oc} – open circuit voltage	37.82 Volt	38.23 Volt
3.	Maximum power voltage V_{mp}	30.29 Volt	31.054 Volt
4.	Short circuit current I_{sc}	8.980 Amp	8.91350 Amp
5.	Maximum power current I_{mp}	8.420 Amp	8.38150 Amp
6.	FF- Fill Factor	…….	76.37320 %
7.	Total efficiency	…….	17.8220 %

C. PV System

Total number of modules in Quaid-e-azam solar power plant are 392,160. The nameplate rating of each module is 255 W. So total capacity of QASP is 255W*392160=100000800W=100MW. An interconnected system of photovoltaic panels which behave as a single power producing cell is called photovoltaic array. Total number of arrays in QASP are 9800 and there are 40 modules in each array. Each array is further divided into upper and lower string. So there are 20 modules in each string. Power from the arrays is combined in a combiner box and then transmitted to the inverter for DC to AC power conversion. The voltages are stepped up to 33kv by a step up transformer and further stepped up to 132kv in the substation.

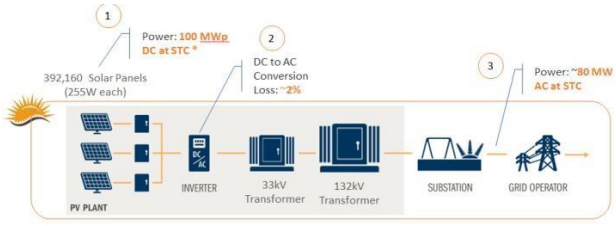

Fig. 3. 100MW solar power plant structure

D. Power Conversion System

The power conversion system is used to maintain the quality and reliability of power supply and to do multiple tasks.i.e.

- Smoothing of pulsating loads.
- Avoid current harmonics
- Compensation of reactive power

In this system single stage three phase inverters are used. Total 100 units are installed each have the capacity of 1 MW. Each unit has two inverters with the capacity of 500kw each. The performance of inverter is affected by high internal temperatures above 50°C. The outside enclosure temperature of Inverter during the hottest days of summer rise up to 68 Degrees Celsius due to direct exposure of sunlight. In order to improve the performance of inverter during extreme temperature conditions and to protect the inverter from overheating, shades are installed over the inverters.

Table 4. Specifications of power conditioning system

Capacity of each unit	500kw
Power Conditioner Model	TC500KH
Rated Input Voltage DC	1000 V
AC voltage range	270-350 V
Max Current DC	1344 A
MPPT range	460-950 V
Output Voltage AC (Rated)	315 V
Rated Frequency	50 Hz
Efficiency	98.42 %

E. Combiner Box

An electrical combiner box holds the electrical connections and separate them from the arrays and site area. Output of multiple arrays is combined in the combiner box that gives the security from over voltages, surge and lighting. Metallic combiner boxes are used in this photovoltaic system which joins multiple panels into independent charging strings

which is connected in the controller.

Fig. 4. Combiner Box

There are 1400 combiner box installed at site and each box has 16 inputs. So 16 arrays are combined in a box. There are also reverse blocking diodes in the combiner box to prevent the reverse flow of power.

III. DUST EFFECTS ON PHOTOVOLTAIC SYSTEM

Photovoltaic modules are constantly presented in open air climate that results in gathering of dust layer, waste of birds and modern deposits like air poisons on photovoltaic panels. Dust deposition fundamentally relies upon dust properties (physical or chemical composition) and weather conditions (atmosphere and landscape topography). Dust assembling on photovoltaic module results in debasement in light transmittance and increment in light reflection[9]. In this way, considerable reduction in yield voltage and current intensity of photovoltaic module is excepted. Extensive variety of studies have been directed to investigate the effects of dust on photovoltaic system. To minimize the dust effect, there should be proper cleaning system of PV modules.

IV. MONITORING RESULTS

1. Production Of Energy

The performance of a grid connected PV system can be analyzed by calculating the daily and monthly energy delivered to the transformer. Total 24 hour energy ($E_{AC\ d}$) and monthly energy ($E_{AC\ m}$) can be calculated as:

$E_{ACd} = \sum_{t=1}^{24} E_{ACt}$	(1)
$E_{ACm} = \sum_{d=1}^{N} E_{ACd}$	(2)

Total energy yeild was measured after DC to AC conversion. Table 5 shows the annual energy produced by the plant.

Table 5. Plant Annual Energy Production Target VS Actual

Year	**Target Production (GWh)**	**Actual Production (GWh)**
1 (July 2015-July 2016)	153.3	160.1
2 (July 2016-July 2017)	152.2	160.2

The targets to QASP are given by "National Electric Power Regulatory Authority (NEPRA) and National Transmission And Dispatch Company (NTDC)". During first year from July 2015-July 2016 the target was given to produce 153.3 GWh of energy and the plant produced 160.1 GWh.

2. PR (Performance Ratio).

Total solar energy converted into electrical energy determines the performance ratio of a solar power plant. It is the ratio between actual energy yield and target yield. PR can be computed as:

$$PR = Energy\ measured(kwh)/\ Energy\ Modeled \quad (3)$$

And,

$$Energy\ modeled(kwh) = Solar\ Irradiance(kwh/m^2) * Active\ area\ of\ panel\ (m^2) * Module\ efficiency \quad (4)$$

Most likely PR is the correct record for PV control plants. However, with the environmental changes PR of the system changes. For example thermal losses increases due to high temperature in summer so PR decrease in summer. For the year 2016, PR of QASP was 0.60. The PR of the best in class System is 0.8[10].

3. AC Power Generation

The output power from the inverter depends upon

- Control of array at the inverter terminal
- Losses inside the inverter

These losses are happened because of switching, backup power and ohmic losses in the semiconductor material. The conversion losses in the inverter are 2% and average total plant losses are 20%. So the plant generates total 80 MW AC power at STC.

V. CONCLUSION

Pakistan largest 100MWp on grid photovoltaic system was dissected, so as to study the photovoltaic system in the climatic states of Pakistan. System was observed from Jan 2016 to Dec 2016 and its Performance ratio (PR) is assessed. The total energy delivered by the QASP was 160.1 GWh in 2016. Performance ratio is enormously influenced by the site temperature and the overall AC generated power is affected by the irradiance, surrounding temperature, dust, and conversion losses during DC to AC conversion. So the total AC power is not as much as the DC input power. This study shows that the plant is meeting the targets set by NEPRA and NTDC and the yearly PR is almost ways to deal with those reported in Germany 0.66, Spain 0.62 and Greece 0.67. So the performance trend is positive. Further studies are required to limit the losses because of dust and towards accomplishing PV produced energy catering to peak load demand.

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