Design of 16.2kW photovoltaic power station for Gumu township primary school in Gaize County Ali Prefecture, Tibet

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Abstract. Gumu Township, Gaize County, Ali Prefecture, is a power free area, which has not yet covered the State Grid. It can only rely on solar energy, wind energy and other township level new energy power stations for power supply, which greatly restricts the development of local economy. This project aims at solving the power consumption problem of gumxiang primary school by adopting solar photovoltaic independent (off grid) power supply mode. According to the actual power consumption of gumu village primary school, a solar photovoltaic power station with a total installed capacity of 16.2kW is planned to be built.

Keywords: Tibet; Photovoltaic power station; Design.

1. Introduction

1.1. Current power situation
Gumu Township, Gaize County, Ali Prefecture, is a power free area, which has not yet covered the State Grid. It can only rely on solar energy, wind energy and other township level new energy power stations for power supply, which greatly restricts the development of local economy. This project aims at solving the power consumption problem of gumxiang primary school by adopting solar photovoltaic independent (off grid) power supply mode. According to the actual power consumption of gumu village primary school, a solar photovoltaic power station with a total installed capacity of 16.2kW is planned to be built.

1.2. Construction scale
The total installed capacity of the stand-alone (off grid) photovoltaic power station is 16.2kW, all of which are photovoltaic energy storage power generation units. Among them, photovoltaic energy storage power generation unit is equipped with 176kWh energy storage battery.

1.3. Geographical position
Gumu Township, Gaize County, Ali Prefecture, is located in the west of Tibet and the east of Ali Prefecture. The average length of the county is about 292 km from east to west and 471 km from north
to south. The geographical center coordinates are 30° 41’ N and 84° 28’ e. The average altitude of the whole county is above 4500m. The oxygen content in the air is only 62% of the sea level. The average rainfall is less than 190mm. The annual average temperature is -0.2 ℃, the average temperature in the cold season is -12 ℃, and the extreme minimum temperature is -44 ℃. The winter lasts for eight months, and the wind is frequent and windy in winter. Gaize County has a hard natural environment, bad climate, frequent natural disasters, mainly snow, wind, hail, drought and so on.

1.4. Solar energy resources
Gaize County in Ali Region ranks first in solar energy resources in the autonomous region and even in the whole country, and is one of the most abundant regions in the world. It has abundant sunshine all the year round, high solar radiation intensity, large direct proportion, small interannual variation, long sunshine hours, annual sunshine hours between 2900-3400 hours, and annual total radiation between 7000-8400 MJ/m². It belongs to the solar energy resource area, which is very suitable for the construction of solar photovoltaic power generation projects [1].

2. Design of photovoltaic system

2.1. Overall design scheme
The project is mainly composed of a photovoltaic module power generation unit with a total installed capacity of 16.2kW, a 20kW off grid inverter and a set of 176kWh energy storage battery pack. Among them, photovoltaic modules are planned to be arranged in the yard of about 118m² in gumu township primary school, while charging and discharging controller, off grid inverter, electrical protection device (lightning protection, load limiting protection, etc.) and energy storage battery are arranged in the room of about 18m² in gumxiang primary school. In the daytime, the photovoltaic power station uses the solar energy to supply power to the load side through the off grid inverter, and stores the excess power into the energy storage battery; At night, the power of the energy storage battery is supplied to the load side by the off grid inverter[2]. While ensuring the daily power consumption of gumxiang primary school, it can also ensure the normal power supply in rainy days for two consecutive days.

2.2. Equipment Selection

| Tab. 1 | Technical parameters of 270Wp monocrystalline silicon photovoltaic module |
|--------|---------------------------------------------------------------|
| **Project** | **Parameter** |
| Electrical properties | |
| Maximum power (Pm) | 270 |
| Output power tolerance (%) | 0~+5 |
| Conversion efficiency of photovoltaic modules (%) | 15.0 |
| Optimum working voltage (Vm) | 30 |
| Optimum working current (Im) | 8.34 |
| Open circuit voltage (Voc) | 37.7 |
| Short-circuit current (Isc) | 9.01 |
| Maximum system voltage (V) | 1000 |
| Rated working temperature of battery (℃) | 46 |
| Peak power temperature coefficient (1/K) | -0.0045 |
| Temperature coefficient of open circuit voltage (1/K) | -0.0032 |
| Temperature coefficient of short circuit current (1/K) | 0.0005 |
| Temperature characteristic | |
| Working temperature | -40℃~85℃ |
| Storage temperature | -40℃~85℃ |
| Maximum snow pressure | 5400Pa |
| Maximum wind pressure | 2400Pa |
| Others | |
| Size (length × wide × thick) | 1650mm×990mm×40mm |
2.2.1. Photovoltaic module. Photovoltaic module is the core component of solar power generation system, and it is also the most important part of solar power generation system. Its role is to convert solar energy into electric energy. In this project, high efficiency 270Wp monocrystalline silicon solar cell standard module is selected as photovoltaic module, and each module is equipped with bypass diode to avoid "hot spot effect" as far as possible; at the same time, fully sealed wiring is adopted to improve the weatherability of solar array [3]. The technical parameters of 270Wp monocrystalline silicon photovoltaic module are shown in Table 1.

2.2.2. Photovoltaic controller. Photovoltaic controller is the control center connecting solar photovoltaic module array and energy storage battery. By adjusting and distributing the input and output power of the system, various control functions of the solar photovoltaic system are realized. According to the change trend of terminal voltage of energy storage battery, automatic control of multiple solar photovoltaic module array in turn on or off can make full use of valuable solar energy resources and ensure the safe and reliable operation of energy storage battery. SD220 100 photovoltaic controller is selected for this project, and the specific technical parameters are shown in Table 2.

### Tab. 2 Technical parameters of SD220 100 photovoltaic controller

| Model                  | SD220 100                  |
|------------------------|----------------------------|
| DC rated voltage (V)   | DC220                      |
| Rated load current (A) | 100                        |
| Input voltage (V)      | ≤1.5Vdc (330V)             |
| Maximum PV power (kWp) | 22                         |
| Number of solar cells  | 8                          |
| Use altitude           | ≤5000m                     |
| Maximum charging current | 12.5A                    |
| Maximum open circuit voltage  | 440Vdc                  |
| Battery over voltage point protection | 310Vdc            |
| Battery overvoltage point recovery | 280Vdc           |
| Over discharge voltage point off | 200Vdc           |
| Over discharge voltage point recovery | 225Vdc           |
| Overcharge overvoltage point cut off | 264Vdc          |
| Over voltage point recovery       | 260Vdc                |
| Voltage drop between panel and battery | 0.7Vdc             |
| Voltage drop between battery and load | 0.1Vdc             |
| No load current         | 0.15mA                    |
| Communication mode      | RS485(Optional)           |
| Operating ambient temperature | -10°C~+40°C           |
| Use altitude            | ≤5500m, the altitude above 1000m needs to be reduced |

2.2.3. Off grid inverter. The off grid inverter mainly converts DC power supply into AC power supply. The inverter configured in this project adopts DC 220 V power supply, which is converted into AC 220 V, 50 Hz sine wave AC power supply after DC-AC inverter, with AC total output plus lightning protection. The capacity of the inverter shall be determined according to the actual load, and the capacity reduction at high altitude shall be considered. Typical technical parameters of 20kW off grid inverter are shown in Table 3.
### Tab. 3 Technical parameters of 20kW off grid inverter

| DC input | KNSI220—20PT |
|----------|--------------|
| Model    | KNSI220—20PT |
| Rated capacity | 20kVA |
| Input rated voltage | 220Vdc |
| Input rated current | 101A |
| Allowable range of DC voltage | 190—300Vdc |
| Rated output power | 16kW |
| Output rated apparent power | 20kVA |
| Rated output voltage and frequency | 220V±1% (single-phase), 50±0.1Hz |
| Output rated current | 90.9A |
| Output voltage accuracy | ±3% |
| Output frequency accuracy | ±1% |
| Total harmonic content | ≤5% |
| Output waveform | sine wave |
| Dynamic response | ≤5% |
| Dynamic voltage transient range | Maximum change of voltage (full load on / off) |
| Power factor | 0.8 |
| Overload capacity | 120% / min |
| Peak coefficient | 03:01 |
| Inverter efficiency | >90% |
| Work environment | |
| Insulation strength | 1500VAC/min |
| Noise (dB) | <50dB |
| Operating ambient temperature | -10°C~+40°C |
| Relative humidity | 90%, no condensation |
| Use altitude | <5000m, (the altitude above 1000m must be reduced) |
| Mechanical parameters | |
| Dimensions (deep × wide × high) | 550×360×750mm |
| Weight | 380kg |

2.2.4. Energy storage battery pack. The DC voltage of the system in this project is designed according to dc220v. Considering the more conservative situation, the discharge depth coefficient of the battery is 0.8, the efficiency is 85%, and the continuous rainy days are considered as 2 days. Considering the redundancy, the calculation method of the required battery capacity is as follows:

(a) The average daily peak power generation of 16.2kW stand-alone (off grid) photovoltaic power station is 59.6kWh. According to the daily power consumption in two days, the required effective capacity is 119kWh, so the required battery capacity is 119kWh / 0.8 / 0.85 ≈ 175kWh;

(b) According to the required battery capacity, 110 2V / 800Ah batteries are selected, 110 in series and one in parallel, so the capacity of the whole energy storage battery is 176kWh.

At the same time, due to the high altitude and cold area in Gumu Township, Gaize County, Ali Prefecture, Tibet, the air is thin and the static electricity is serious, so the electrical components face the risk of reducing the insulation performance. Therefore, the main control box of energy storage battery pack of this project should have the following advantages [4]:

(a) Improve the insulation performance and overcome the influence of thin air;

(b) Strong anti-static ability to ensure system safety and personnel operation safety;

(c) The control performance is good, and it is suitable for the control strategy in high altitude and cold area.
3. Electrical design
Because the altitude of Gumu Township in Gaize County of Ali Prefecture of Tibet is above 4500m, the high altitude environment not only reduces the electrical gap and external insulation strength; the results show that the arc extinguishing performance, on-off ability and electrical life of the switchgear with air medium arc extinguishing are reduced; it also reduces the air cooling effect, reduces the heat dissipation capacity and increases the temperature rise. Therefore, in the electrical design of photovoltaic power station in high altitude area, we should pay attention to the following three points: first, the selection of switching devices and control devices; second, the arrangement of primary and secondary lines and protective measures of conductors; thirdly, different structural designs are adopted.

It is very important to select switching devices for plateau type electrical equipment, especially for high-voltage devices. The air gap between conductors in the cabinet and between conductors and ground shall be treated according to the requirements of insulation distance in high altitude area to prevent insulation breakdown, or electrical equipment with higher voltage level, such as voltage transformer, current transformer and insulator bushing, shall be used. The electric clearance and creepage distance are used to meet the above-mentioned factors that need to be corrected for altitude rise. For the control devices, generally electronic devices, weak current control, high reliability, less affected by altitude, easy to solve the problem of high altitude.

For the selection of main switch of electrical equipment, the insulation voltage should be appropriately larger. The normal rated voltage of power grid is 400V. At the altitude of 4000m, frame switch and molded case switch with insulation voltage of 1000V can be selected to ensure larger external insulation strength margin, so as to reduce the impact of high altitude and low pressure, Low voltage components, such as current transformers, should be specially treated to increase the creepage distance and electrical clearance, so as to ensure that the secondary side power frequency withstand voltage and other indicators can pass. Other secondary side weak current devices can basically be selected according to ordinary devices.

The key point is to meet and consider the following four requirements:
(a) The external insulation strength should be large enough to meet the requirements of modification due to the decrease of external insulation strength caused by the decrease of air density at high altitude, so that the impulse voltage and power frequency withstand voltage of the product can meet the requirements of high altitude;
(b) For the mechanical transmission parts inside the complete set of devices, such as operating handcart and release, the influence of material deformation caused by high altitude temperature change on tolerance should be considered, which should be considered in the design of corresponding devices;
(c) The reduction of air pressure or air density will reduce the cooling effect of air medium and cause the influence of temperature rise. Especially for high current devices, it is necessary to consider the use of capacity reduction. The capacity reduction coefficient is determined according to the altitude. For details, please refer to the technical description of the device manufacturer;
(d) The selection of insulation materials should try to select the insulation materials (such as DMC or SMS molding compound) with little change in temperature difference and high degree of anti-aging. While ensuring high strength, the deformation and aging degree should be small, so as to adapt to the places with high requirements for insulation coordination, such as low-voltage bus frame. At the same time, attention should be paid to the creepage distance required by the altitude correction coefficient Electrical clearance dimension requirements.

4. Conclusion
The key point of the structural design of plateau type electrical equipment is to arrange enough space for the installation of bus system. According to the above clearance, creepage distance, isolation distance and other dimensional parameters need to be modified according to the altitude correction coefficient, so it is different from conventional products. In the dimension chain of the structure, it is necessary to consider and reserve a larger dimension based on the altitude factor, so the whole structure needs to be redesigned. Nowadays, structural design is based on three-dimensional software, and the corrected data
can be used directly to check the size interference. The interference inspection of the assembly parts around the selector bus bar is carried out according to the corrected data, so the design simulation is convenient to ensure that the dimensions of the corresponding electrical clearance and creepage distance meet the correction requirements; At the same time, we should also pay attention to the influence of altitude on the flashover distance, and properly consider the increase of the flashover distance when arranging the device installation position. In a word, the structure design of plateau type complete equipment must consider the change of dimension chain relationship, and design the structure that meets the requirements of correction value.

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