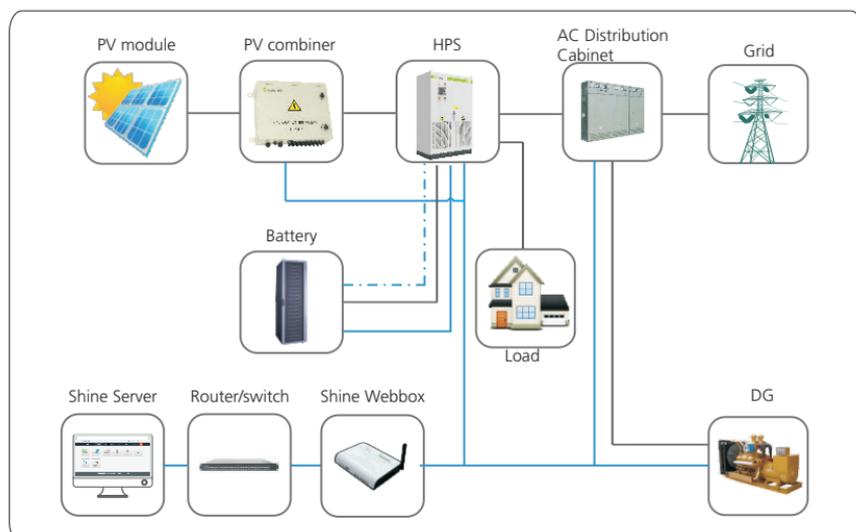


How to design a Solar-DG-Battery energy storage system

There is always no or poor utility in some remote mountainous areas and islands, diesel generators become the main power source which provide power for human lives. In recent years, as the prices of photovoltaic power generation equipment such as solar panel, battery, and inverter declines, the cost of photovoltaic system has been decreasing year by year. Under the current trend of increasing diesel price, photovoltaic off-grid system has also begun to attract more and more attention. Practice has proved that solar-DG-battery hybrid system, which uses mainly solar, diesel only for supplementary, is with greater economic efficiency than DG.



When doing economic analysis, we should consider total costs and total benefits over the lifespan of the system. Photovoltaic power generation has high CAPEX, but no need for supplementing raw materials at a later stage, it is with lower OPEX. The CAPEX of diesel generator is low, but it requires regular fuel inputs at a later stage, it is a continuous investment and has high OPEX.

1. Solar-DG-Battery energy storage system cost analysis.

Lifespan cost of Solar-DG-Battery energy storage system = investment cost + operation and maintenance costs + financial costs. Investment cost consists of purchase cost of solar panels, batteries, inverters, power distribution cabinets, panel frames, cables, other equipment and materials, and also construction and transportation cost. Operation and maintenance cost consists of operators' salary expense, maintenance cost of electrical equipment such as inverters, cleaning fees of solar panels, etc. The operation period of photovoltaic system is generally 20-25 years. Unlike the case where coal and fuel power generation requires the purchase, transportation, storage of energy, and disposal of residuals, the input energy of the photovoltaic system comes from the sun. During the operation period, the photovoltaic system does not require other energy sources, and almost no residual is generated. If the PV arrays are installed in a fixed manner, there are no vulnerable rotating components in the PV system, and the service life of major electrical equipment such as solar panel is more than 20 years. The maintenance of the system is also easy, and the annual maintenance costs just about 5% of total system cost.

The benefits of photovoltaic systems are directly proportional to the amount of generated electricity, and the factors that determine the amount of generated electricity by photovoltaic system include the rated capacity of PV modules, the site solar radiation, and the efficiency of photovoltaic system. PV module rated capacity is the peak value of PV module output power obtained under the standard test conditions. Since the site conditions are different from the standard test conditions, the actual output power of PV modules mainly depends on the amount of solar radiation on site. In addition, the photovoltaic system output power should also be included in the impact of various losses and aging derating.

Photovoltaic power generation is affected much by the weather, and it can generate little electricity during rainy days. Therefore, the local weather should be taken into account when designing the system. For users who require electricity, we should consider the duration continuous rainy days when designing system.

2. Fuel power generation cost analysis.

The lifespan cost of fuel power generation is: the investment cost of diesel power generation, which mainly includes the purchase cost and engineering cost of diesel generator sets and supporting facilities; the fuel cost during the life cycle; the operating and maintenance cost in the lifespan of diesel generator sets (mainly maintenance cost, oil and other consumables costs). Among the various expenses, the proportion of fuel costs is relatively large. It is determined by the total power generation, fuel consumption, and average diesel price during the lifespan of the diesel generator sets.

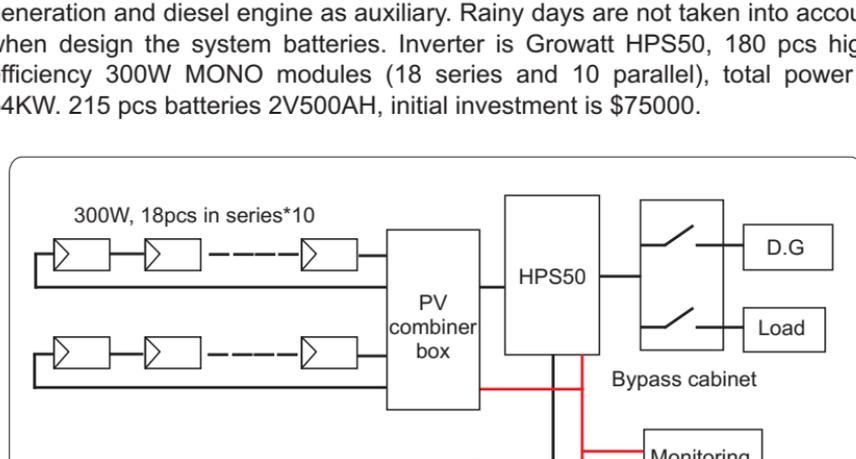
Under normal circumstances, the conversion efficiency of diesel generator sets is about 31%, the weight of 1L diesel is about 0.835kg, the heat value of 0# diesel per kilogram diesel is 10200 kcal/kg, about 42676.8 kJ(10200*4.2J) , 0.835 kg diesel calorific value = 0.835*42676.8 kJ, 1 kWh = 1000W*1H = 3600 kJ, 35635.128 kJ/3600 = 9.89 (kWh), considering conversion efficiency of diesel generator 1L diesel can generate 3kWh electricity.

50kW Solar-DG-Battery energy storage system case reference:

The following is a comparison of a 50KW system between diesel generator system and Solar-DG-Battery energy storage system, installed in an island. The main load is lighting, fans, seawater desalination equipment, 80kWh consumption during the day and 120kWh consumption at night. Average insolation is 4.5 hours, and continuous rainy days are 2 days.

The diesel engine is Cummins 4BT3.9G2, and the equipment cost is \$7500. The average price of diesel is \$1083/ton, the operation and maintenance cost is 7% of the fuel cost, while there is a big difference between diesel transportation and storage fees. Whereas, off-grid systems are in remote areas, and in some areas transportation and storage costs even more than diesel price, for the case of calculation, this project we take it as 5%. The 50kW diesel engine generates 40 kWh in one hour and consumes 10.5 kilograms of diesel. The total cost is \$12.74. The cost of diesel power generation is \$0.32 /kWh.

Solar-DG-Battery energy storage hybrid system adopts photovoltaic power generation and diesel engine as auxiliary. Rainy days are not taken into account when design the system batteries. Inverter is Growatt HPS50, 180 pcs high-efficiency 300W MONO modules (18 series and 10 parallel), total power is 54KW. 215 pcs batteries 2V500AH, initial investment is \$75000.



Cost comparison between diesel generator system and Solar-DG-Battery energy storage system, all data comes from China market:

| No. | Items | 50 kVA D.G | S-DG-B ESS |
|-----|--------------------|--|---|
| 1 | Initial investment | D.G: initial investment is \$9584, others \$1667; Total \$11251. | Inverter, solar panel, batteries, D.G.et; Total \$75000. |
| 2 | Maintenance cost | \$1000/year | \$500/year |
| 3 | Consumable | Fuel: \$1100/ton | Batteries replacement every 4 years, inverter replacement every 15 years, Total cost: \$1333.3/year |
| 4 | Output | 40 kWh/h, required by load | 240 kWh/day, 87600kWh/year |
| 5 | Cost per kWh | \$0.32 /kWh | \$0.18 /kWh |

As the price of grid-connected PV systems and solar panels has continued to decline in recent years, the high-efficiency solar panels have been reduced to \$0.32/watt. Compared with fuel-power generation, Solar-DG-Battery ESS has great advantages.

In areas without grid, diesel generator sets and photovoltaic systems constitute a hybrid power supply system. Compared with diesel engine sets, Solar-DG-Battery ESS has many advantages such as low maintenance cost, less fuel consumption, less noise, and power generation cost is less. A large number of expensive batteries can be saved, and the overall power generation cost is also reduced, compared with pure off-grid PV system.