Research and Practice of Designing Hydro/ Photovoltaic Hybrid Power System in Microgrid: Chinese Yushu Case

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1.Introduction

Small-hydro power is a very popular kind of power supply in rural area. In China, there are 45,000 small-hydro power plants and they supplies millions of rural population. However, energy of hydro power plant is so different from one season to another, and in dry season, it would lower down or stop because of low water. On the other hand, there is usually abundant of solar irradiance in the same area so that hydro/photovoltaic (PV) hybrid power system will guarantee a reliable power supply in a whole year. Nowadays, the cost of PV system has been reduced to a relative low level, and then the hybrid system is also economically feasible.

In this paper, the objective is focused on research and practice of designing a hydro/PV hybrid power system in an isolated microgrid. In 2011, a 2MWp PV station is established in Chinese Yushu, where is far away from main power grid and is supplied by 12MW of total capacity of hydro power plants. The PV station is connected to hydro power plants and load via 35kV power grid.

2.Demand analysis of hydro/PV hybrid power system

In Qinghai province, China, there is an isolated power grid in Yushu County. In 2010, the grid is powered by 2 hydro power stations with total capacity of 12.8MW, but the available power in dry season (from October to March) will reduce 50%. The peak demand in winter is 13MW and the peak time appears between 8:00pm-11:00pm.

Therefore, a 2MW PV station with battery is planned in the power grid and shown in Fig.1. The station should also meet following demands:

1) The station mainly supplies during peak load time which is about 4 hours.
2) The discharging-depth of battery keeps less than 50% to prolong the lifetime.
3) The station connects to 35kV transmission line.
4) In normal operation, the grid can dispatch the station's power.
5) When the grid is down, the station can supply a 100kW-class critical load.

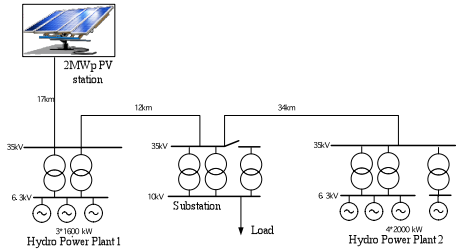

Figure #1 Hydro/photovoltaic hybrid power system in Yushu County

3.Proposed structure of MW-class PV system with battery bank

The proposed structure of the 2MWp PV system is shown in Fig.2. The station is composed of 20 branches of 100kWp PV system. The total capacity of PV module is 2MWp.

In each branch, there is a 760kWh battery bank integrated into DC bus and the total capacity of battery is 15.2MWh. With an initial state of full charge, the battery can stably produce 2MW for about 3.8 hours before SOC decreases below 50%, so that the station can serve as a controllable unit during peak load time even in night. On the other hand, the 2MWp PV module is estimated to produce 8MWh per day in Yushu. With an initial SOC of 50%, the battery can store 7.6MWh of electricity, which is 95% electricity of PV in a daily cycle.

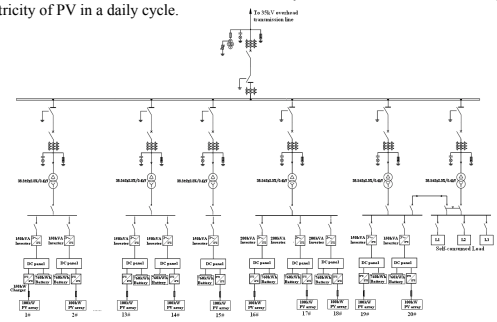

Figure #2 Proposed structure of the 2MWp PV station in Yushu County

In this station, a 1000Ah@2V battery unit is used. 190 units are connected in series, and then, 2 branches are connected in parallel. It is a great challenge to charge such a battery bank. The rated voltage between 2 terminals of the battery bank is 380V, the charging-power is around 100kW and the charger should perform maximum power point tracking (MPPT). A 150kW DC/DC charger is developed by Institute of Electrical Engineering (IEE) and main parameters are shown in table 1.

Table 1. Main parameters of 150kW DC/DC charger

Input power	150 kW	Range of MPPT voltage	450~900 V
Max. of input current	350 A	Control method of PV	MPPT
Rang of battery voltage	330~450 V	Max. of charging current	450A
Control method of charging	constant-voltage limitary-current	Max. efficiency	98%
Parallel ability	Yes	Ambient temperature	-25 ~ +50℃
Protection	IP20		

When the grid is down, the 150kVA inverters of 19# and 20# branch can turn into autonomous mode to supply the critical load. A 150kVA inverter with characteristic of synchronous generator is developed by IEE and main parameters are shown in table 2. The character is to solve the issue of controlling several inverters in parallel and dispatching load in autonomous mode. The total capacity of 20 inverters is 3.15MVA and all of them are controllable, so it provides a 3.15MVA potential capacity during peak load time.

Table 2. Main parameters of 150kVA inverter

Range of input voltage	335~447V	Max. input current	366A
Rated AC power	150kVA	Rated AC current	182A
Operating mode	Grid-on/autonomous	Mode switching-time	<200ms
In grid-on mode			
THD of AC current	<5%	Power factor	1-0.7(lead and lag)
Control of AC power	Yes	Max. efficiency	95.4%(with transformer)
In autonomous mode			
THD of AC voltage	<5%	3-phases unbalance factor	100%
Max. efficiency	96.6%(with transformer)		

The station is finished by the end of 2011, and the photos of the station and main equipments are shown in Fig. 3. The monitor and control system in Fig.3(d) is developed by IEE, and it provides 2 control modes: local-control mode and remote-control mode. At present, there is no automation system at grid-level in Yushu, and the local mode allows the operator to dispatch power at PV station-level or control all of equipments in the control room. The remote mode is reserved for future use.

(a) 2MW PV station with battery in Yushu County (Nov. 2011)

(b)150kW DC-DC Charger

(c)150kVA Inverter

(d) Monitor&control system

Fig.3 Photos of 2MW PV station with battery in Yushu County and main equipments

4.Conclusions

(1) In designing a hydro/PV system, there are 4 main considerations including energy demand, peak power demand, battery lifetime and generation cost on kWh basis.

(2)A PV system structure with MWh-class battery in DC bus is proposed. In grid-on mode, it can act as a controllable unit. When grid is down, it can turn into autonomous mode and supply the critical load. In 2011, a 2MWp PV station with the proposed structure was finished in Yushu, China.

(3) There are 2 great challenges. One is to charge a MWh-class battery with a PV-MPPT function. The other is to develop a 100-kW class inverter with characteristic of synchronous generator. A 150kW DC/DC charger and a 150kVA inverter have developed by IEE and demonstrated in Yushu.

Bibliography

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