

Combination control for photovoltaic-battery-diesel hybrid micro grid system

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Abstract. It is facing resource shortage and environmental pollution around the globe, until the emergence of new renewable energy technology has reinvigorated traditional techniques. Development of renewable energy generation in China needs the joint efforts of all social sectors from policy to technique. Distributed generation combining with battery applied in micro-grid relieves a problem of resource shortage, and ensures load operation when power grid fault urgently. In this paper, photovoltaic is described briefly first. Then photovoltaic-battery-diesel micro-grid is established according to the situation about geographical environment, what is more workflow of the system is analyzed. Control strategy is shown according to condition of micro-grid.

Keywords: photovoltaic-battery-diesel micro-grid, distributed generation, running mode of micro-grid.

1 Introduction

With the increasing acute global energy crisis and environmental problem getting worse, renewable generation technology was born at the right time. DG (distributed generation) technology based on renewable energy is developing rapidly. DG combining with battery becomes a hot project about researching micro-grid in current. DG with small size locating on the user side is that using distributed resource to be multiple power generation equipment which comprehensive and gradient use of resource by 10 (35) kV and lower voltage grade accessed renewable energy. Renewable energy mainly include solar energy, wind, gas, biomass energy and so on. Developing key point of distributed generation is wind generation and PV (photovoltaic) in China. At present, with progressing of battery, distributed resource combining with battery was used widely. Due to adding DG with large size to grid, grid-connected is facing a big challenge to reconciling contradictory between DG and grid, releasing impact of DG to grid, therefore, concept of micro-grid is proposed. Micro-grid is a type of independent controllable system consisting of DG, battery, converters, load, monitor and protector. At the same time, micro-grid supply power and heat, and run with grid-connected or independent [1]. Combining DG and battery technology applied in independent micro-grid which can solve power supply in

remote area and improve reliability of power supply. That is a good way to promote energy saving and emission reduction, and reduce the loss as well.

Currently, research on micro-grid technology is in the infancy with great gap between Occident and China. Many countries have established project model about micro-grid. Greece has established independent micro-grid of wind-PV-diesel-battery in Kythnos. There are many micro-grid pilot project in China, micro-grid pilot project in Yudaokou Village, Weichang County, Chengde City, Hebei Province is one of them. Zhejiang Power Grid establishing an independent micro-grid system in the south island of the east China sea is the first power supply containing DG in China, which guide to DG independent micro-grid. Nowadays, PV output power stability, which lead the development of power grid. As we all know, solar resource is rather abundance in Liaoning Province where PV is generalized gradually in large and medium-sized city.

This paper has been given a kind of independent micro-grid containing DG based on resource superiority in Liaoning Province. This paper shows characteristic of independent micro-grid first. Then the paper analyzes power electronic device of independent micro-grid applying DG and introduces technology about micro-grid. It analyzes PV-battery-diesel system that is established according to the situation of geographical environment. And micro-grid control is analyzed. Finally, economic benefit and value of PV-battery-diesel is illustrated in Liaoning Province.

2 Basic principle of micro-grid

2.1 Basic structure of micro-grid

DG works when micro-grid with alone operation. PV-battery-diesel micro-grid consists of PV unit, storage unit and diesel generator unit. Micro-grid can work off grid, that is micro-grid can work alone with DG [5-6].

2.1.1 PV unit

Solar energy can be transferred to power by PV unit, which is composed of PV array, junction box, inverter, etc. AC transferred from solar energy is collected by PV component via inverter to load. PV system can work parallel with grid and work alone as well. It will work with grid connected inverter, if PV system works parallel with grid, otherwise, it needs to work with battery [7-9].

1. Grid connected inverter

Grid connected inverter is key of grid connected system. Grid connected inverter transfer DC from PV array to AC, working with grid together.

DC from solar cell through booster circuit rise voltage to the DV (directional voltage) of inverter needed. Inverter bridge circuit DV after booster circuit converse to AV (alternating voltage) is commonly used. Anti reverse of DC side is to avoid power

flow from grid to PV array. Filter is to restrain harmonic flowing to grid, in order to reducing the influence of grid. When there is any external fault in inverter, closing down the contactor to make protection and isolation of inverter come true.

2. Independent PV system

Independent PV system is to consuming PV power in internal closed circuit without connecting with grid. Namely micro-grid containing DG works alone when there is any fault in grid. Independent PV system needs to work with battery. Controller is key of power distribution, in order to managing charge and discharge of battery.

2.1.2 Storage unit

Storage unit is to supplying power to load via PV or grid in real time consisting of battery, bi-converter, charge and discharge controller, etc. Charge and discharge controller can manage battery effectively. That is composed of collecting circuit, protecting circuit, DC/DC main circuit and driving circuit. PV array charges battery alone, until reaching a certain value when battery power is insufficient. During charging, charge and discharge controller collect voltage of battery constantly and stop to charge battery till reaching a certain value.

When battery is overflow and light is strong enough, PV array stop to charge battery but start to afford load. When light is weak and load is increasing, PV array and battery supply power to load together. Bi-converter applying in storage is an important means about renewable resource, which is applicable to dynamic storage. Namely power from battery supply to load when grid is fault or solar power is insufficient. Charging battery when power is sufficient. Battery make the lash-up effect in independent micro-grid.

2.1.3 Maximum power point tracking control

Under a certain light intensity and temperature, the maximum power of PV array is output when PV array output a certain voltage. The point of PV array arriving at the top of power curve is named MPP (Maximum Power Point). Adjusting work point of PV array according to external factors is to making the point become MPP. The technology is named MPPT (Maximum Power Point Tracking) which makes battery get most [10].

At the same temperature, the stronger light intensity shining to PV array is, the higher power is, otherwise, power is lower. In the same light conditions, the higher temperature of photocell is, the lower output power is, otherwise, the power is higher. Incremental conductance method is a better way. According to output characteristic of PV array, MPP is:

$$dP = dU = 0 \quad (1)$$

Where, P is output power of PV array. U is output voltage.
For photocell, there is:

$$P = UI \quad (2)$$

$$\frac{dP}{dU} = I + U \frac{dI}{dU} = 0 \quad (3)$$

$$\frac{dI}{dU} = -\frac{I}{U} \quad (4)$$

$$\frac{I}{U} + \frac{dI}{dU} \quad (5)$$

Therefore, judging the symbol of formula (5), MPPT is known. When the symbol is positive, this point is on the left of MPP, output voltage should be decrease. When the symbol is negative, this point is on the left of MPP, output voltage should be increase. When the magnitude is 0, this point is right MPP.

2.2 Working process of micro-grid

1. Normal operation of grid

Power from PV array supply to battery first, until reaching a certain value. Power from PV array is sent to collect bus via collector. Supplying solar energy to load No.1 and load No.2 first, which makes sure output is maximum and getting most. Grid supply power to load when solar energy is insufficient. When solar energy is sufficient, supplying power to both micro-grid No.1 and No.2 first, returning back to grid and flowing to low level second. Diesel generator stops when power is enough. Namely disconnect KG1 and KG2, close KG3.

2. Grid is fault

When there is fault, system switch to independent micro-grid operation automatically. PV energy supply to substation No.1 and No.2, excess energy flow to battery. When PV energy is insufficient, battery works with depth of discharge to meet the demand of power quality. When PV energy and battery are both insufficient to afford load, using diesel generator. Closing KG1 and KG2, load No.1 and No.2 are supplied together among diesel generator, storage system and PV system. Closing KG1 and KG3, diesel generator, storage system and PV system in No.1 side supply power together to load No.1 and No.2. Closing KG2 and KG3, diesel generator afford load No.1 and No.2 respectively with PV system and storage system until trouble removal.

3. Resumption of power supply

After removing trouble, system adjust voltage phase of inverter automatically. Voltage frequency, phase of micro-grid bus and of AC-bus are in allowed range. Micro-grid operation transferred from independent mode to parallel mode [11].

3 Control strategy

3.1 Operation mode

Micro-grid contain a variety of DG. Control mode need to collect information of control switch in real time to real-time switch. When working connected with grid, DC/AC of PV-battery system keep DV constant, DC/DC of battery control output power according to charging current, in order to remaining output power of photocell is smaller than charging power.

When there is any fault in grid, DG in micro-grid detects that bus voltage or frequency is over range, PV-battery system works into standby situation. Controller of micro-grid mode detects that loop switch of micro-grid close first. Enter independent state second. When external voltage is normal, loop switch disconnect, PV-battery system stop to independent operation, working connected with grid again.

When micro-grid works alone, KG1, KG2 and KG3 close or disconnect according to different conditions. When KG1, KG2 and KG3 are all disconnect, micro-grid No.1 and No.2 work independently with PV-battery system. When KG3 disconnect with KG1 and KG2 close, micro-grid No.1 and No.2 work respectively with PV-battery-diesel system, otherwise work alone. When KG3 close, micro-grid No.1 and No.2 work together parallel. The condition is in PV-battery mode with whole grid. Operation method of micro-grid is shown in Tab. 1.

Table 1. Operation method of micro-grid

KG1	KG2	KG3	Operation method	Operation mode
-	-	-	Small grid No.1 works alone Small grid No.2 works alone	Small grid with PV-battery mode. Battery is main power.
+	-	-	Small grid No.1 with PV-battery-diesel works Small grid No.2 works alone Small grid No.1 works alone	Small grid with PV-battery-diesel mode. Diesel generator is main power.
-	+	-	Small grid No.2 with PV-battery-diesel works	
+	+	-	No.1 and No.2 work respectively, whole grid with PV-battery-diesel work	
-	+	+	No.1 and No.2 work parallel, whole grid with PV-battery-diesel work	Whole grid with PV-battery-diesel mode. Diesel generator is main power.
+	+	+	No.1 and No.2 work parallel, whole grid with PV-battery-diesel work	
+	-	+	No.1 and No.2 work parallel, whole grid with PV-battery-diesel work	
-	-	+	No.1 and No.2 work parallel, whole grid with PV-battery work	Whole grid with PV-battery mode. Battery is main power.

In this table, - means disconnect, + means close.

Operation mode control depending on switching of mode control collect information of grid or micro-grid in real time with smooth way to switch operation mode flexibly. There are three operation methods. In whole grid of PV-battery mode and PV-battery-diesel mode as an example.

3.2 Distribution protection control

Due to accessing DG, flow direction of distribution network change from one-way to two-way. Therefore, micro-grid must be allocated perfect protection for keeping safe in different conditions. Employing PCS mainly, and AC protection, AC over/under voltage protection and over temperature protection managed by centralization. Differential protection locate fault quickly and accurately. Adopting passive optical network to achieving collection of grid data. When system detect over current, over voltage or over temperature, blocking pulse, cutting off breaker, stopping and warning at once. AC protection sets timing and limiting current protection mainly. When AC over/under voltage protection detect there is abnormal, cutting off contactor according to the setting value before and stopping to transmitting power or charging battery. Over temperature protection protect hardware temperature. Beyond that, digital temperature protection is provided. Once the temperature is too high, it might turn into standby until temperature recovery with clearing sign automatically.

3.3 Grading operation of micro-grid

When micro-grid works alone, affording load by PV-battery-diesel system . When power is enough, micro-grid works without grading operation. When power can afford a certain amount of load, abandoning load in lower level first, affording main load only. When power is earning of many, returning back to grid and afford another load in next level.

4 Conclusion

Generated by renewable energy is more and more becoming centralized access and distributed access simultaneously in China. Combining DG and storage technology according to geographical features. DG works parallel with grid and switching to work alone automatically, when grid is in trouble. When micro-grid works alone, employing many kinds of energy to keeping supply power in real time. Double protection and smooth switching in varieties of modes, in order to ensure power supply and quality. Economic benefit is pointed out in this paper.

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