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Modeling and Simulation of DIGSILENT-based Micro-grid System

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Abstract

The accurate modeling of micro-grid access to power system planning and design stage needs is the primary problem to solve. This paper modeled the micro grid photovoltaic power generation system ,including silicon solar cell, photovoltaic inverters, battery energy storage system, and the micro power distribution system .The use of power system analysis software (DIGSILENT) of actual power system simulation, the simulation results verify the model's correctness. In the power grid fault disturbance, the light intensity of disturbance and the load disturbances, the simulation results show that the optical storage combined with micro network has fast dynamic response characteristics, and its network of grid-connected voltage influenced by the changes of the light and load is little, while more affected by the network fault influence.

Keywords: *micro grid, silicon solar cell, photovoltaic inverter, battery energy storage system introduction*

1. Introduction

With the increasing depletion of conventional energy sources and environment deterioration, the development of the clean energy has become our country to solve the shortage of energy and protect environment is an important strategic task. Represented by photovoltaic power, the distributed clean energy has less pollution, high reliability, and high efficiency of energy utilization . At the same time distributed energy access to power grid brought negative effect; photovoltaic, wind power and other intermittent energy power fluctuation of electric energy quality problems. In order to reduce the distributed energy simple parallel operation on the power grid and user impact, reducing its access to the electric energy quality and other aspects of the impact, micro power grid is considered into the research field of intelligent distribution network [1-3]. Micro grid system modeling is a micro power grid operation analysis, model includes the following parts: the photovoltaic power generation systems, battery energy storage system and a micro grid distribution system [4-5].

2. Photovoltaic Power System Modeling

Photovoltaic grid-connected generation system consists of a photovoltaic array, the inverter and controller, inverter photovoltaic cell is produced from the power inverter into sinusoidal current injection system; the controller tracks the photovoltaic maximum power point to control the grid-connected inverter’s current waveform to the network to transmit power and photovoltaic array maximum power phase equilibrium. The controller is composed of a single-chip microcomputer or general digital signal processing chip as core components; voltage source inverter is mainly composed of power electronic switching devices connected inductor, a pulse width modulation form to the power transmission grid. Typical photovoltaic grid-connected system structure diagram includes: photovoltaic array, inverter and integrated control protective device [6-7], as shown in Figure 1.

Figure 1 shows the inverter is the core of photovoltaic grid-connected generation system, the maximum power tracking controller and a synchronization waveform controller belong to the inverter part, so the whole modeling work can be divided into three parts:the solar photovoltaic cell model, grid connected control model and network protection control model.

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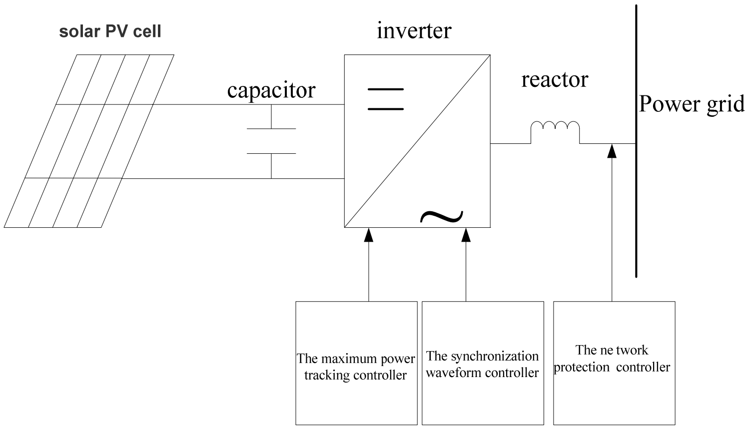

Figure 1. The Structure of Photovoltaic Paralleled in System

2.1. Standard Test Environment of the Silicon Solar Cell Engineering Simplification Model

A simplified nonlinear mathematical model:

$$I = I_{sc} \cdot \left\{1 - \alpha \left[e^{\beta \cdot U} - 1\right]\right\} \tag{1}$$

$$\alpha = I_0 / I_{sc} \tag{2}$$

$$\beta = q / AkT \tag{3}$$

Where q is the electron charge,T is the absolute temperature of solar cell,K is the Boltzmann constant, A is diode curve factor, I_o is reverse saturation current, I_{sc} is short circuit current, U is equivalent diode voltage, α and β are unknown parameters, can be represented by the following method:

The formula (1) into a voltage expressions, available:

$$V = \frac{1}{\beta} \cdot \ln \frac{(1+\alpha) \cdot I_{sc} - I}{\alpha \cdot I_{sc}} \tag{4}$$

In the maximum power point, $I = I_m$, $U = U_m$ in the open state , $I = 0, U = U_{oc}$. U_{oc} is the open-circuit voltage, I_m is the maximum power point current, U_m is the maximum power point voltage, P_m is maximum power.

Substituted into type (4):

$$U_m = \frac{1}{\beta} \times \ln \frac{(1+\alpha) \cdot I_{sc} - I_m}{\alpha \cdot I_{sc}} \tag{5}$$

$$U_{oc} = \frac{1}{\beta} \times \ln \frac{(1+\alpha)}{\alpha} \tag{6}$$

Considering the normal temperature condition can be solved:

$$\alpha = \left[\frac{I_{sc} - I_m}{I_{sc}}\right]^{\frac{U_{OC}}{U_{OC} - U_m}} \tag{7}$$

$$\beta = \frac{1}{U_{oc}} \times \ln(\frac{1+\alpha}{\alpha}) \quad (8)$$

Therefore, based on the 4 electric parameters $(U_{oc} \backslash I_{sc} \backslash U_m \backslash I_m)$ provided by the manufacturers ,the e nonlinear mathematical model can be created .or as long as the use of manufacturers to provide 4 electric parameters, according to type (7) and (8) to derive parameters and, again by type (1) can be obtained by the IV characteristics of solar cell. In this paper, based on the DIgSILENT simulation platform controlled DC current source established the arbitrary intensity and temperature of the silicon solar cell engineering simplification model.

In order to verify the accuracy of the model, the simulation results with the photovoltaic battery and the parameters (such as shown in Table 1) provided by the manufacturers are consistent [8-9].

Table 1. The Technical Parameter of STP180S-24/Ad 125 Single-crystal Silicon Photovoltaic Module

Parameter	value
Type	STP180S-24/Ad
Uoc	44.8V
Um	36V
Isc	5.29A
Im	5A
Pmax	180Wp

Taking the day illumination 1000W / m2, component temperature 25 DEG C, using the DIgSILENT/PowerFactory simulation tools in the controlled current source can draw a photovoltaic cell IV curve as shown in Figure 2, which shows the simulation results is consistent with the real data (the best working voltage 36V, the optimal working current peak power of 5A, 180Wp)

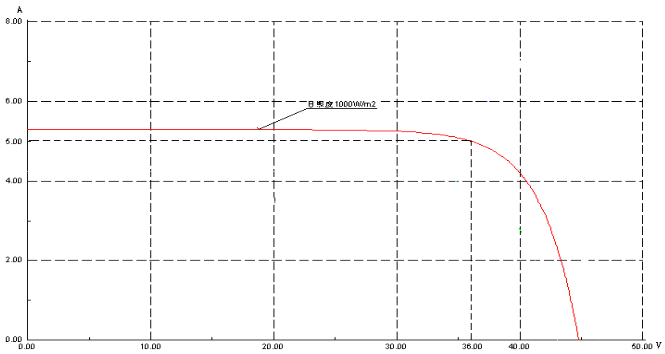

Figure 2. The Characteristic Curve of 125 Single-crystal Silicon Photovoltaic Module

The block of modification of flux error status has two main functions, i.e. to detect flux sectors and to perform dynamic overmodulation. Some block components inside this block are depicted in Figure 5. For convenience, the tasks of the blocks can be grouped into two areas as marked in the Figure 2. The upper group area is responsible to determine the appropriate flux error status according to the flux sector and the threshold value of $\Psi_{sq,2}$. The bottom group area is assigned to determine the flux sector and the threshold values for each sector. The dynamic overmodulation mode is activated when a sudden large torque error detected by the relay block (as hysteresis comparator) requests the “switch2” (as selector) to select the appropriate flux error status (i.e. produced by the upper group area), otherwise, the “switch2” will select the original flux error status.

2.2. Photovoltaic Inverter Control Model

There Without considering the saturation factor of inverter under the influence of ideal inverter by type (9) simulation:

$$U_{ACd} = K_0 \cdot P_{md} \cdot U_{DC}$$
$$U_{ACq} = K_0 \cdot P_{mq} \cdot U_{DC} \quad (9)$$

Where the U_{DC} is AC voltage, U_{ACd} and U_{ACq} represented the d axis and q axis component respectively. Under the Sine wave modulation, $K_0 = \frac{\sqrt{3}}{2\sqrt{2}}$, P_{md} and P_{mq} represented Inverter Modulation ratio. The other control point inverters get the modulation ratio as the input of the inverter. In general, the inverter uses the loop current feedback control, according to the outer loop control target to determine the inner loop current feedback control as the reference value, and then through the loop current feedback control to get the modulation ratio. Usually the inverter control objectives are the output active power, reactive power, but in the photovoltaic power generation system in the output power of the system is changing with the as the external conditions. When light intensity, temperature change, the controller will take action, adjust the working voltage to the optimal operating point. Therefore the inverter contained controller can get the d axis and q axis component. by the control target U_{dc_ref} and reference value of reactive power Q_{ref} .

2.3. Photovoltaic System

Photovoltaic power generation system as shown in Figure 3:

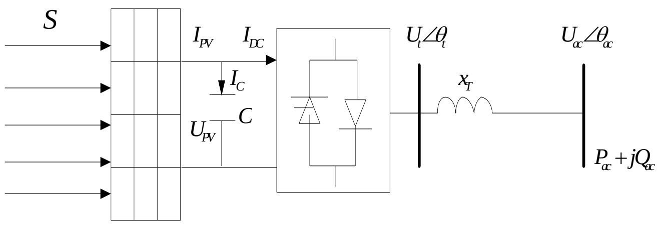

Figure 3. The Model of Photovoltaic Paralleled in System

In the modeling process, think inverter ideal, with power grid connected through reactor. Photovoltaic array emitted power:

$$P_{PV} = U_{PV} \cdot I_{PV} \quad (10)$$

Photovoltaic power generation system is injected into the communication system for the active:

$$P_{ac} = \frac{U_t U_{ac}}{x_T} \sin(\theta_t - \theta_{ac}) \quad (11)$$

Injected into the communication system for the reactive power:

$$Q_{ac} = \frac{U_t U_{ac}}{x_T} \cos(\theta_t - \theta_{ac}) - \frac{U_{ac}^2}{x_T} \quad (12)$$

Consider the process of charge and discharge capacitance:

$$P_{PV} = U_{PV} \cdot I_{PV} = C \cdot U_{PV} \cdot \frac{dU_{PV}}{dt} + P_{ac} \quad (13)$$

And separately for voltage source inverter export AC voltage magnitude and phase angle, the inverter control system decision. In addition, the inverter AC / DC voltage is as follows:

$$U_t = \frac{\sqrt{3}}{2\sqrt{2}} m \cdot U_{PV} \quad (14)$$

M is modulation ratio, type (10) to (14) that determines the overall model of grid connected interface.

2.4. Battery Energy Storage System Modeling

Energy storage battery in micro power network is very important. It is used for optimal power output and stable control of clean energy system and it is possible to adopt the small capacity energy storage, through rapid energy access, realize large power adjustment and rapid absorption of" saved energy" or" power shortage", thereby improving clean energy system operation stability, improving electric energy quality,enhance the reliability of the system to realize rapid corresponding to power.

Equivalent circuit model is often used In the field of electrical engineering, detailed energy storage battery equivalent circuit as shown in Figure 4. The open circuit voltage is SOC (important parameters reflecting the battery charged state function), used to describe the dynamic characteristics of the impedance of battery by the internal resistance of the battery and the other resistance.

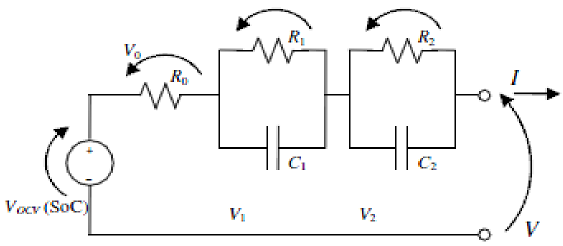

Figure 4. The Detailed Equivalent Circuit of Stored Energy Battery

$$\begin{aligned} V &= V_{OCV}(SoC) - \left(R_0 + \frac{R_1}{1+sR_1C_1} + \frac{R_2}{1+sR_2C_2} \right) I \\ &= V_{OCV}(SoC) - R_0 I - \left(\frac{K(1+sK_1)}{(1+sK_2)(1+sK_3)} \right) I \end{aligned} \quad (15)$$

Type (15), in addition to the open circuit voltage, the other parameters and current are nonrelated with soc. The Table 2 is a typical model parameters.

Table 2. The Model Parameter of LiFeP04 Battery Typed A123-M1

Parameter	value
R_0	0.07
K	-0.047288
K_1	597.56
K_2	32.668
K_3	1996.7

2.5. Distribution System Modeling with the Micro Grid

Electronic systems with micro grid can be modeled considering the characteristic of various parts of it: if there is big difference of each parts, then need to establish practical network topology of the system; if each part contains identical or close characteristics, then establish equivalent network topological structure of the system. Considering the photovoltaic component and the same characteristic of the storage battery used in practical engineering field, usually PV module and storage battery are the same type products with the same manufacturers. The characteristics of the Micro power grid load are almost the same. This paper established micro grid electronic equivalent system model, the photovoltaic power generation system, an energy storage battery system adopt centralized equivalent model, micro grid load characteristics near the same load with General Load-2 said, General Load-1 said other loads, the load characteristics and size can be in the simulation according to requirements set.

3. Simulation Analysis of the Micro Grid Dynamic Response

In the validation of the accuracy, this paper focuses on the analysis of micro grid access to distribution of the network and no energy storage under extreme conditions, the output power of the power network voltage and the dynamic response characteristics. The main power grid considering fault disturbance, light load disturbance disturbance, three case, regardless of power grid fault condition and micro grid and off network operation mode switch. In electronic system with equivalent topological structure of the network environment as follows: Simulation of fault disturbance simulation, light intensity disturbance simulation and load disturbance simulation.

3.1. Grid Fault Disturbance

Figure 5 shows an example system equivalent network diagram.

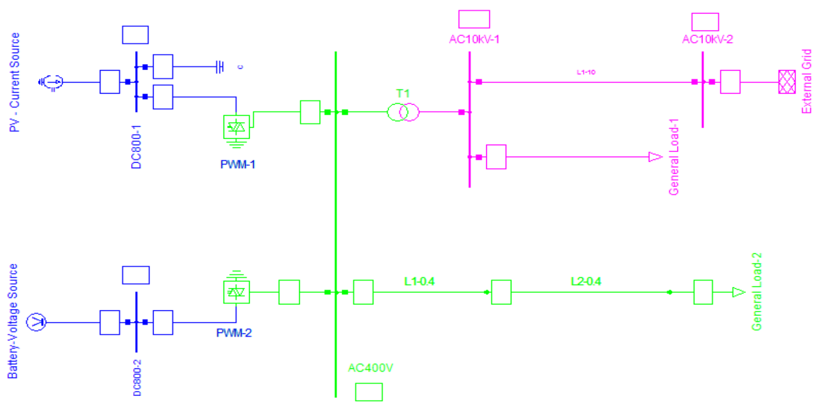

Figure 5. The Topological Diagram of Equivalent Network of Distribution Subsystem

The Figure 5 shows the equivalent network, a micro power grid and China Southern power grid connection line L1-10 in 1.1s fault, 1.3s three-phase short-circuit fault clearance. Micro grid load for the pure active load 0.2MW. Photovoltaic power generation system with maximum power point tracking, control model, which is equal to 0. Energy storage system using, control, which = - 0.2MW, 0. Power system fault disturbance, and the dynamic response characteristics of network voltage as shown in Figure 6.

Figure 6 shows and network voltage failure fault during 0.968p.u, and network voltage fluctuations down to 0.012p.u, fault after excision and network voltage restored to 0.969p.u. The qualified level [10].

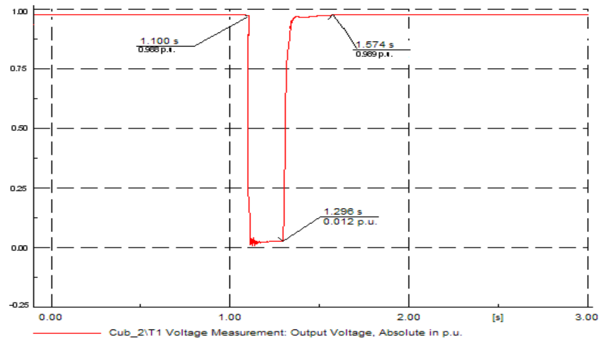

Figure 6. The Voltage Dynamic Response of Parallel Point (based 1kV)

3.2. Light Intensity Disturbance

Hypothesis of photovoltaic power generation system initial working light intensity of 1000W/m2 conditions, a time of light intensity jump to 900W/m2, as shown in Figure 7.

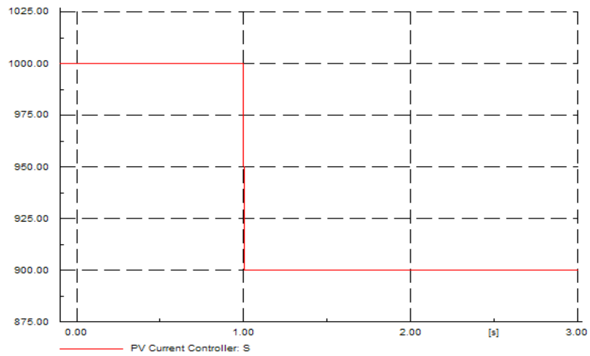

Figure 7. The Step Change of Intensity of Illumination

The Figure 7 shows the equivalent network, photovoltaic power generation system in light intensity disturbance conditions, and the dynamic response characteristics of network voltage as shown in Figure 8:

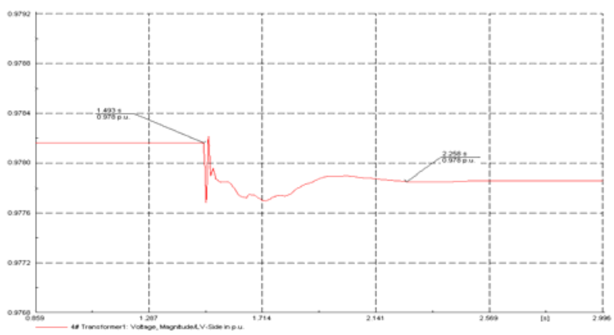

Figure 8. The Voltage Dynamic Response of Parallel Point (based 1kV)

Figure 8 shows the light intensity mutation and network voltage stability in 0.978p.u, light intensity after mutation and network voltage is always in 0.978p.u. So near the small fluctuations, final voltage restored to 0.978p.u. the qualified level.

3.3. Change of Load Disturbance

A micro power grid in the initial loading of 300kW, in the 1.1s step in increments of 20%, this time and network voltage response characteristics as shown in Figure 9 (red, blue line as to load and network voltage):

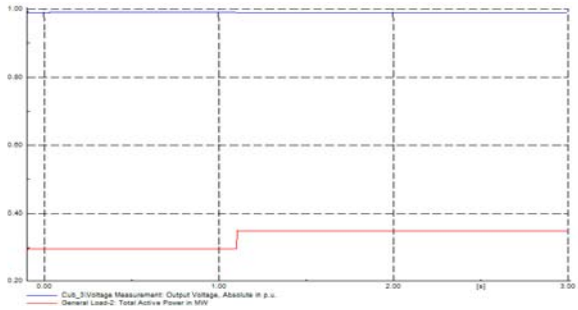

Figure 9. The Voltage Dynamic Response of Parallel Point (based 1kV)

4. Conclusion

This paper based on the DIGSILENT simulation platform controlled DC current source established engineering simplification model for arbitrary intensity and temperature of the silicon solar cell, photovoltaic inverters, battery energy storage system, and electronic system with micro gird. The simulation results show that the model has high accuracy. In power grid fault, illumination variation, mutation load under the conditions of the simulation analysis shows: optical storage combined with micro network with fast dynamic response, both in the disturbance after transient response. The access, in network fault disturbance and network voltage fluctuations; in light and load disturbance, and outlets of the voltage can be maintained in the normal range. The optical storage combined with micro network on power systems voltage by light and the influence of load changes little, affected by the network fault influence.

Acknowledgements

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