

General electromechanical transient model of grid connected photovoltaic power generation system and its comparative analysis with electromagnetic transient model

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Abstract. order to solve the problem of complex electromagnetic transient model and slow calculation speed of grid connected photovoltaic power generation system, a general electromechanical transient model for grid connected photovoltaic power generation system is proposed. The model contains small electrical components and high frequency switching devices. It is completed by pure mathematical calculation. The model is simple and fast. The electromechanical transient model is simulated in PSCAD/EMTDC, and the results are in good agreement with the simulation results of electromagnetic transient model, and the simulation time is greatly reduced, which verifies the correctness and effectiveness of the electromechanical transient model. The universal electromechanical transient model provides a model reference for large-scale grid connected photovoltaic power plant simulation and modeling, and has practical value.

1. Introduction

With the development of new energy, smart grid and micro grid technology, grid connected photovoltaic power generation system has been widely used, and has broad prospects for the development of [1-2]. In the dynamic analysis of grid photovoltaic power generation system with the need to adopt both transient model accuracy and efficiency, in a previous study, the photovoltaic power generation system model usually adopts two kinds of models, is the trend of [3] model, it is modeled as a power source is simple, without considering the dynamic process, the model is only suitable for the trend analysis. And cannot be used for transient analysis; the other is based on the corresponding photovoltaic power system specific circuit or electromagnetic model [4-5], strictly reflect the maximum power point tracking of photovoltaic power generation system (MPPT) control algorithm and the inverter circuit and its control logic, this model is very detailed. In summary, analysis of the common characteristics of the photovoltaic power generation system to function, and for power system electromechanical transient simulation needs, the formation of a universal modeling method.

This paper briefly introduces the structure of grid connected photovoltaic power generation system, and then puts forward the general electromechanical transient model of a grid connected photovoltaic power generation system, and the internal structure is introduced in detail, finally through the PSCAD/EMTDC simulation of the electromechanical transient model, and compared with the



electromagnetic transient model simulation results verify the correctness of the and the effectiveness of the electromechanical transient model.

2. grid connected photovoltaic power generation system

At present, the common grid connected photovoltaic power generation system has single stage grid connected photovoltaic power generation system, two stage grid connected photovoltaic power generation system and multi-level grid connected photovoltaic power generation system, as shown in figure 1. In the single stage grid connected photovoltaic power generation system, the photovoltaic array is directly connected with the DC/AC inverter. The inverter converts the DC energy output from the photovoltaic array to the AC power that meets the demand of the grid. The inverter needs not only the conversion of power, but also the realization of MPPT. In the two stage grid connected photovoltaic power generation system, the output power of the photovoltaic array is connected to the DC/DC circuit and the DC/AC inverter, and the DC/DC circuit achieves the MPPT and boost effect, [6] The control methods of [7] are various, such as fixed voltage method, conductance increment method, disturbance observation method and so on, MPPT. The use of DC/AC grid connected inverter voltage inverter, the main control voltage control and current control, voltage control is the system as the controlled voltage source, the output voltage and grid voltage with the same frequency and phase; current source control is the system as a controlled current source, current and grid voltage of the output of the same frequency and phase.

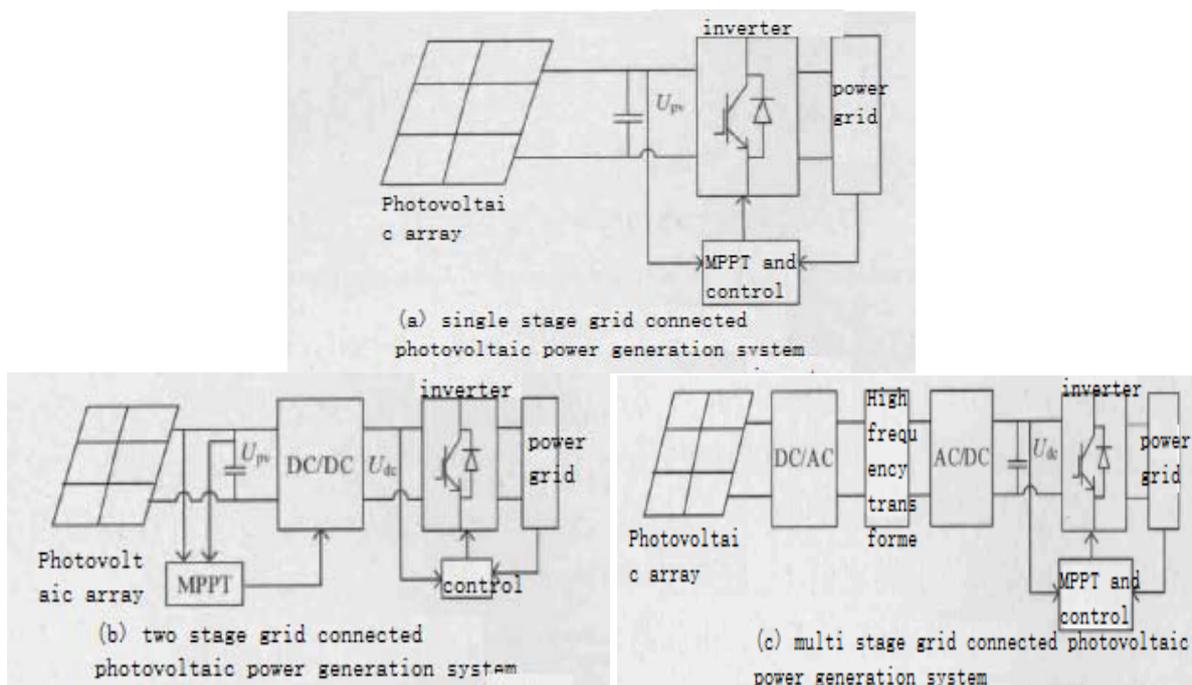


Figure 1. Structure of common photovoltaic system

There are many kinds of control methods for DC/AC grid connected inverters with voltage source input and current source output. [8]. 2 electromechanical transient model of photovoltaic power generation system.

From the aforementioned, grid connected photovoltaic power generation system may be single, double or multi stage MPPT algorithm, this paper presents a general electromechanical transient model, as shown in Figure 2. S , T respectively for photovoltaic array environment light intensity and temperature, V_{pvm} is the voltage at the maximum power point of the photovoltaic array, the characteristics of the PV array's decision, and as the input reference voltage MPPT output module,

V_{pvm1} and DC link MPPT output voltage V_D , output power of photovoltaic array P_{pv1} as DC transform input, decided the terminal voltage of photovoltaic array, namely V_{pv1} . The function of DC link is to maintain the DC bus voltage as a constant value by balancing the DC side power P_{pv1} and the AC side power p_{De} .

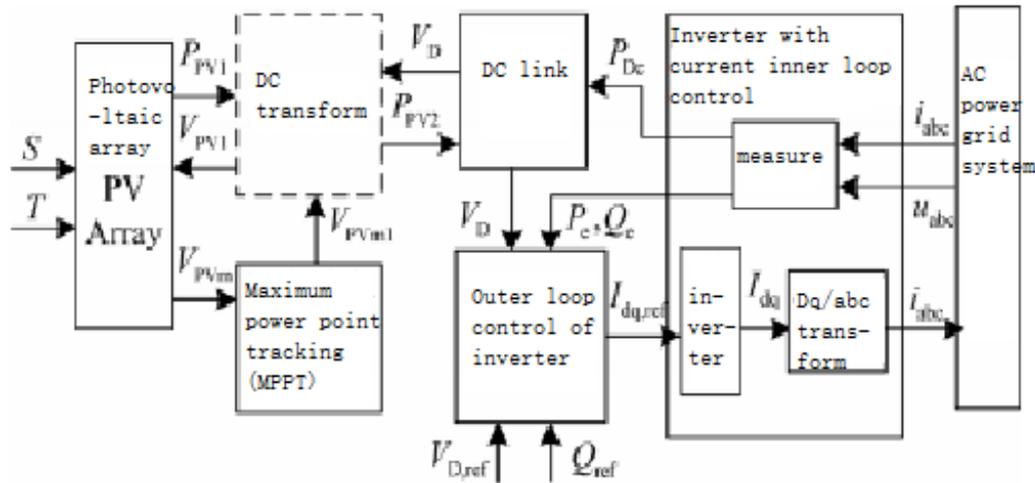


Figure 2. Signal relationship of electromechanical transient model

2.1. Photovoltaic cell model

In order to avoid the influence of different photovoltaic cells on modeling, the general behavior model of photovoltaic cell [9] is adopted. The mathematical equation of the model corresponds to the formula in (1) (6), the modeling parameters only include: standard battery short-circuit current under the environment of I_{sc} , the open circuit voltage U_{oc} , maximum power and maximum power voltage U_m current I_m of the 4 parameters, we can get the output characteristics of photovoltaic cells, namely the Z curve.

$$I = I'_{sc} \{1 - C_1 [e^{U/(C_2 U_{oc})} - 1]\} \quad (1)$$

$$C_1 = (1 - I'_m / I'_{sc}) e^{-U'_m / (C_2 U_{oc})} \quad (2)$$

$$C_2 = (U'_m / U'_{oc} - 1) [\ln(1 - I'_m / I'_{sc})]^{-1} \quad (3)$$

$$I'_{sc} = I_{sc} \Delta I, I'_m = I_m \Delta I, U'_{oc} = U_{oc} \Delta U, U'_m = U_m \Delta U \quad (4)$$

$$\Delta I = [1 + \alpha(T - T_{ref})] S / S_{ref} \quad (5)$$

$$\Delta U = [1 - \gamma(T - T_{ref})] \ln[e + \beta(S - S_{ref})] \quad (6)$$

2.2. Implementation of general electromechanical transient model

In order to verify the accuracy and the validity of the proposed electromechanical transient model, the electromagnetic transient model simulation, this paper established the electromagnetic and electromechanical transient model of three-phase grid connected photovoltaic power generation system in PSCAD/EMTDC, with a double stage type grid connected photovoltaic power generation system as

an example, the outer loop uses PI control inverter the inner parameters of A circuit simulation, the electromechanical transient model as shown in Figure 3, the model parameters are shown in Table 1.

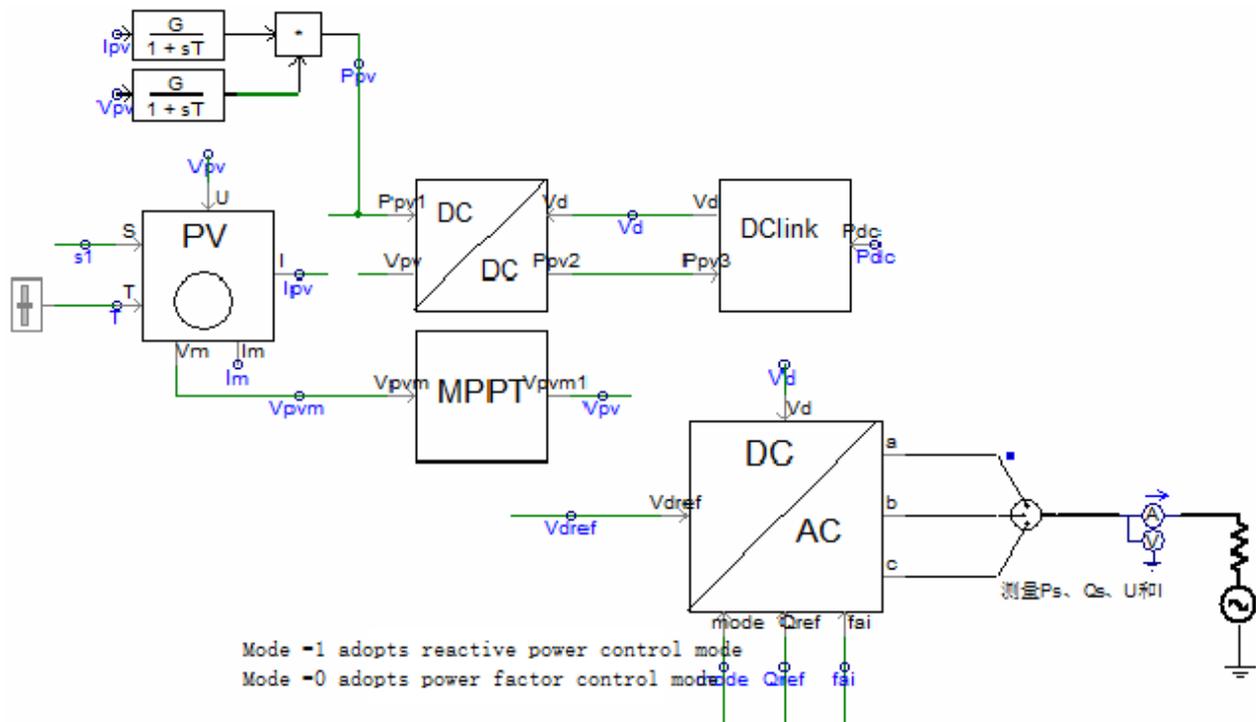


Figure 3. Simulation circuit of electromechanical transient model

Table 1. Parameters of electromechanical transient model

Modular	Symbol	Significance	Numerical value
Photovoltaic array	Um	Maximum power point voltage	17.4V
	Im	Maximum power point current	3.56A
STP062-12/Sc	Uoc	Open circuit voltage	21.8V
polysilicon	Isc	Short-circuit current	3.78A
	Np	Parallel number	30
	Ns	Number of series	24
MPPT	γ	Time constant of pure delay	0.05s
	T	First order time constant	0.7s
Outer ring of inverter	Kp	Proportionality	3
	Ki	Coefficient	0.5
Inner loop of inverter	bd1, bq1	Load time constant	0.003s
	ad1, aq1	Integer time	0.0008s

3. Comparison of electromechanical transient and electromagnetic transient simulation results

The power curve of the system side is given in Fig. 4. After the illumination intensity increases, the active power increases, and the reactive power remains stable at 0 after transient transient, that is, the power factor of the system side is 1, which accords with the control target. When the intensity of illumination increases, the output power of PV array increases, and the system side current increases, which can be seen from Figure 5 and figure 6. Fig. 7 is the DC bus voltage curve, and the DC bus voltage reaches a steady state after a transient transient when the light intensity changes. In addition, from the comparison between Fig. 4 and Fig. 7, it can be seen that the simulation results of electromagnetic

transient and electromechanical transient are in good agreement, which shows that the electromechanical transient model is reasonable.

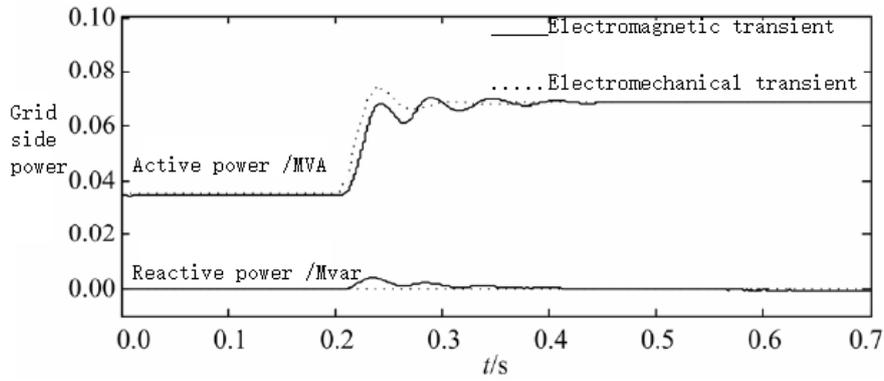


Figure 4. Power of grid side

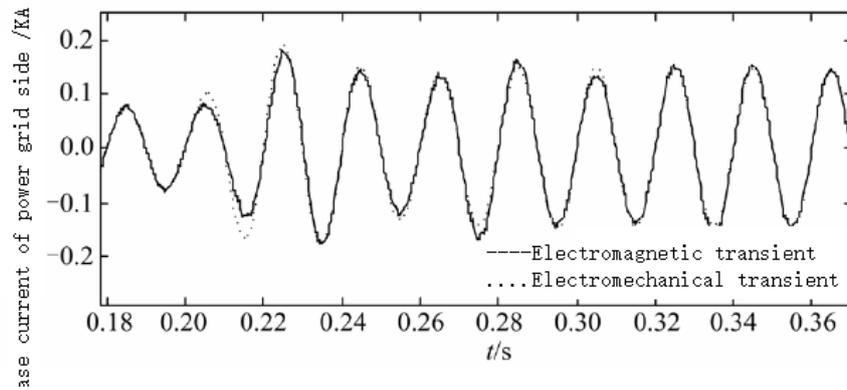


Figure 5. Current of phase A

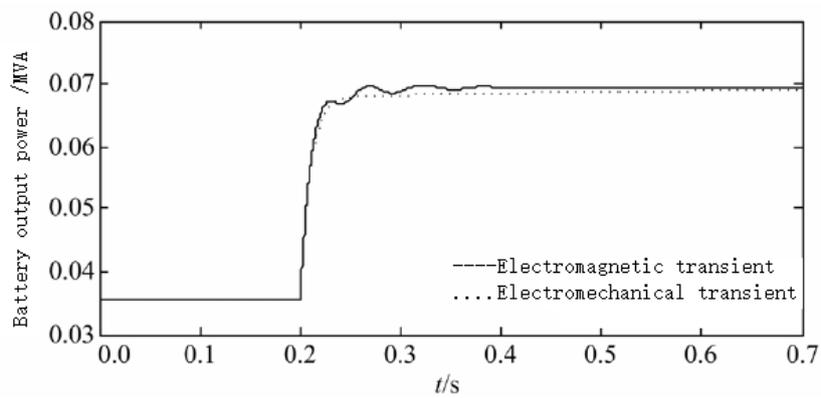


Figure 6. Photovoltaic output power

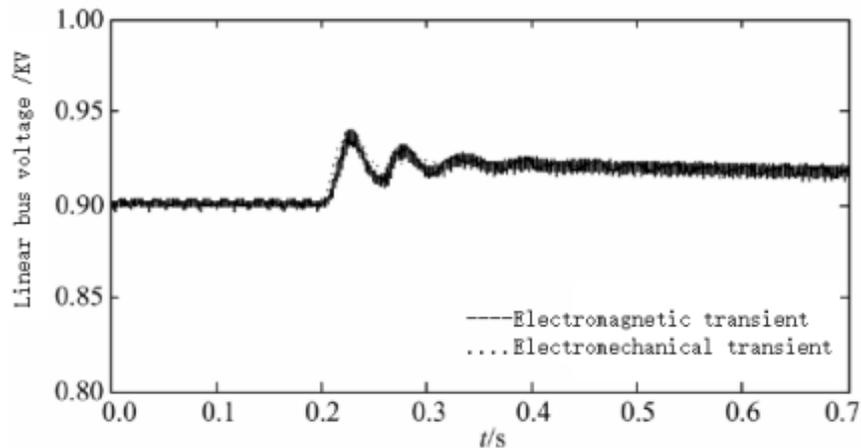


Figure 7. DC bus voltage

From the simulation time, the electromagnetic transient model completed 46.6 s simulation, while the electromechanical transient model completed only 4.1 s simulation, indicating that the electromechanical transient model is much faster, greatly saving the simulation time.

4. Conclusion

In this paper, a general electromechanical transient model of grid connected photovoltaic power generation system is proposed, and the electromechanical transient and electromagnetic transient models of photovoltaic power generation system are established in PSCAD/EMTDC, and the simulation results of the two models are compared.

The electromechanical transient model does not contain electrical components and high-frequency switching devices, which greatly increases the simulation step size and improves the calculation speed. Compared with the electromagnetic transient model, the simulation time is greatly saved. The electromechanical transient model can be used in the transient simulation of large-scale photovoltaic power generation system, which provides a model reference for the modelling and Simulation of photovoltaic power station and the transient stability research of grid connected photovoltaic power generation system.

References

- [1] LI Dong-hui, WANG He-xiong, ZHU Xiao-dan, et al. Research on several critical problems of photovoltaic grid-connected generation system [J]. Power System Protection and Control, 2010, 38 (21): 208 - 214.
- [2] ZHANG Zhe-bo, LIU Jian-zheng, MEI Hong-ming. Study of reactive power compensation characteristics on a three-phase double-stage grid-connected photovoltaic power system [J]. Transactions of China Electrotechnical Society, 2011, 26 (1): 242 - 246.
- [3] Varma R K, Khadkikar From Seethapathy R. Nighttime application of PV solar farm as STATCOM to regulate grid voltage [J]. IEEE Trans on Energy Conversion, 2009, 24 (4): 983 - 985.
- [4] [YAO Zhi-qing, ZHANG Qian, LIU Xi-mei. Research on simulation of a three-phase grid-connected photovoltaic generation system based on PSCAD/EMTDC [J]. Power System Protection and Control, 2010, 38 (17): 76 - 81.
- [5] DU Chun-shui, ZHANG Cheng-hui, LIU Xin-zheng, et al Control strategy on the three-phase grid-connected photovoltaic generation system with shunt active power filter [J]. Transactions of China Electrotechnical Society, 2010, 25 (9): 164-168.
- [6] GAO Jin-hui, TANG Jing. A novel MPPT method for PV systems [J]. Power System Protection and Control, 2011, 39 (23): 21 - 29.

- [7] HU Xue-feng, GONG Chun-ying. A new predictive control strategy for photovoltaic grid-connected inverters and its DSP implementation [J].Transactions of China Electrotechnical Society, 2011, 26 (1): 102 - 106.
- [8] RUI Qi-hua, DU Shao-wu, JIANG Wei-dong, et al.Current regulation for three-phase grid-connected inverter based on SVPWM control [J].Power Electronics,2010, 44(4): 4 - 6.
- [9] JIAO Yang, SONG Qiang, LIU Wen-hua. Practical simulation model of photovoltaic cells in photovoltaic generation system and simulation [J].Power System Technology, 2010, 34 (11): 199 - 202.