The study for selecting an appropriate value of input capacitor in dispersed generation PV inverter

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Abstract- Most PV (Photovoltaic) inverters are a voltage source type. Normally an input capacitor of this type is connected at the input of an inverter to keep the DC voltage constant. However, it does not seem to be well known how to determine the appropriate value of the capacitor. By developing non-linear transient analysis, the author suggests a guideline for this approach. An implicit trapezoidal formula was used to do this calculation.

1. Introduction

Generally, dispersed generation PV inverter has an input capacitor, which is located in front of the inverter, so that it is able to keep the voltage constant (we call this 'input capacitor').

Input capacitor, however, is not well known what is the appropriate value of it, there has been various kinds of values in the domestic market. Also, the input capacitor has some shortcomings. It is susceptible to heat, has a short lifetime and is expensive.

Thus, it is desirable to select the appropriate or low value of input capacitor in dispersed generation PV inverter. Therefore, the author suggests a method to select the appropriate value of input capacitor.

2. The method for choosing the appropriate value of input capacitor

2.1 Principle of the capacitor load method

In order to analyze the characteristics of PV output voltage and PV output current through input capacitor, only PV array and input capacitor are shown in Fig. 1.

When switch is closed, at t=0, the equation of charging voltage and current represent a equation (1).

$$v' = (\frac{1}{C})i = (\frac{1}{C})f(v) \tag{1}$$

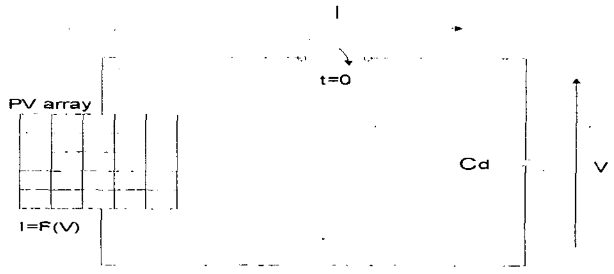

Fig. 1 Charging circuit of input capacitor C_d

where, v' is the time derivative of $v(=\frac{dv}{dt})$. C and i represent electrostatic capacitance of the capacitor and output current from the I-V curve, respectively.

At eq.(1), the I-V curve characteristic of PV array can represent $i = f(v)$.

If Voc (open voltage) and Isc (short current) in PV array are represented,

$$V = \frac{v}{Voc}, I = \frac{i}{Isc}, T = \frac{1}{C}(\frac{Isc}{Voc})t$$

Thus, eq.(2) can be normalized by eq.(1).

$$V' = \frac{dV}{dT} = I = F(V) \tag{2}$$

where $F(V)$ is normalized $f(v)$ in the same way. If $i = f(v)$ were a linear function, eq.(1) or (2) could be easily solved by the ordinary Runge-Kutta-Gill method. However, it is difficult to apply it since the actual relationship between i and v is non-linear.

2.2 Numerical analysis of the non-linear differential equation

It is known that a numerical integration by the implicit trapezoidal rule having the second-order accuracy is highly stable and it has been successfully applied for stiff systems where the differences among time constants are large.

The formulation of a differential equation from eq.(2) by a step by step solution is described in the following paragraph. The notation of (V) or (T) means a state value at voltage V or time T. Suffix j shows a present, given state and $j+1$ corresponds to an unknown state for the next time step.

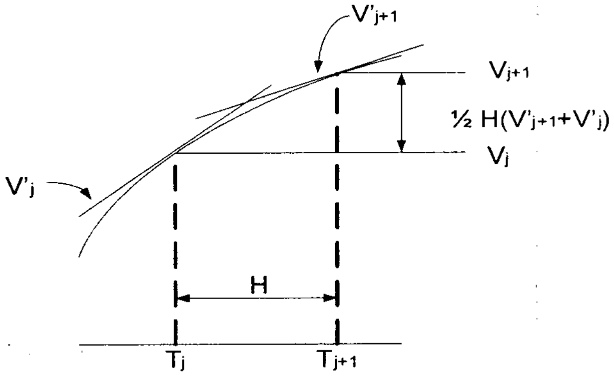

Fig. 2 The basic principle of trapezoidal formula

According to Fig. 2, voltage V_{j+1} at time $T = T_{j+1}$ is given by

$$V_{j+1} = V_j + \frac{H}{2}(V'_{j+1} + V'_j) \qquad (3)$$

where

$$V_{j+1} = V(T_{j+1}) \ ; \ V_j = V(T_j)$$

$$V'_{j+1} = F(V_{j+1}) \ ; \ V'_j = F(V_j)$$

$$T_{j+1} = T_j + H \ ; \ H = \frac{1}{C}\left(\frac{Isc}{Voc}\right)h$$

The last h denotes the time step size defined by $t_{j+1} - t_j$ and H means the normalized time.

Eq.(3) can be rewritten using an unknown term A_{j+1} and known term B_j by,

$$A_{j+1} = V_{j+1} - \frac{H}{2}F(V_{j+1})$$

$$B_j = V_j + \frac{H}{2}F(V_j)$$

$$A_{j+1} - B_j = 0 \qquad (4)$$

In this way the solution of the differential eq.(2) can be given by solving the algebraic eq.(4) where V_{j+1} is unknown.

2.3 The calculation method for obtaining K_{PM}

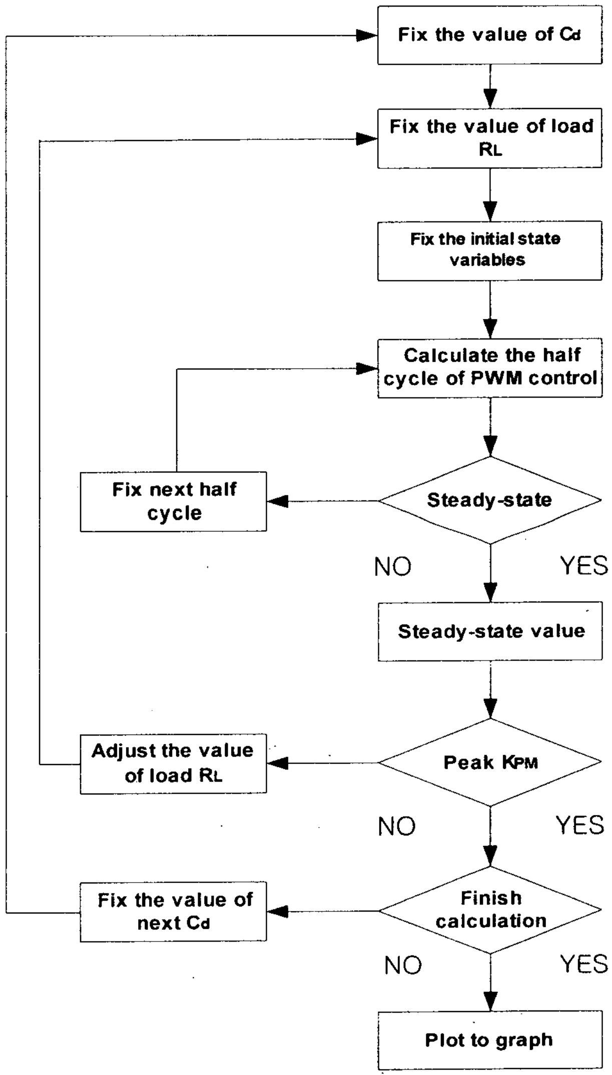

Fig. 3 The calculation method for obtaining K_{PM}

K_{PM} is the efficiency of MPPT(Maximum Power Point Tracking). The MPPT means that the operating point of PV output is equal to P_{MAX} . At this point, K_{PM} has the maximum value of 1.

$$\frac{P_{OP}}{P_{MAX}} \qquad (5)$$

P_{OP} : Operation point of PV array output

P_{MAX} : Maximum point of PV array output

2.4 The change of K_{PM} due to the variation of input capacitor

Fig. 4 shows a simulation circuit, which is realized using PSIM program.

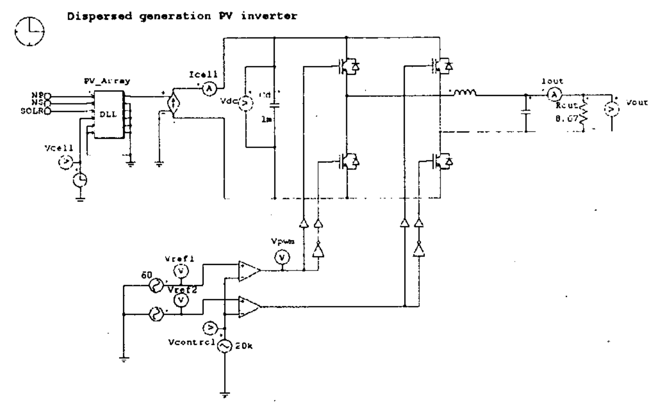

Fig. 4 The circuit of dispersed generation PV inverter

The circuit in Fig. 4 is used to perform simulation. The inverter of Fig. 4 performs the PWM control (Sine wave is a 60[Hz], triangle wave is a 20[kHz]).

The initial conditions of this circuit are that fill factor is 0.7, Voc (open voltage) is 293[V] and Isc (short circuit) is 14.9015[A]. Thus, initial load resistance R is set a 19.66[Ω](=Voc/Isc) and input capacitor C_d is a 457[μF].

Fig. 5 shows that when the value C_d of input capacitor is a 457[μF], PV voltage, PV current and have been plotted.

When the input capacitor increase to 10[mF], the result is shown in Fig. 6 The steady state of K_{PM} does not have value of 1 at 0.83ms [milli second], which is the half cycle of PWM control in the circuit, even at 1.2ms.

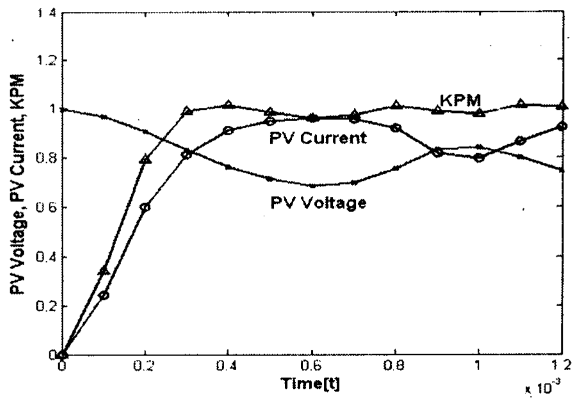

Fig. 5 PV voltage, PV current and K_{PM} where C_d is a 457[μF]

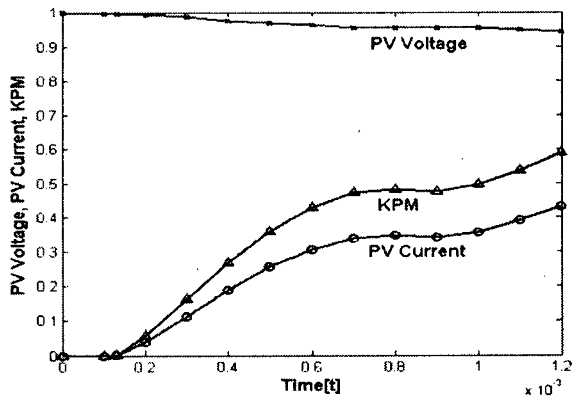

Fig. 6 PV voltage, PV current and K_{PM} where C_d is a 10[mF] until 1.2ms

Fig. 7 shows the result of the long time analysis compared to Fig. 6 K_{PM} has value of 1 at 7ms.

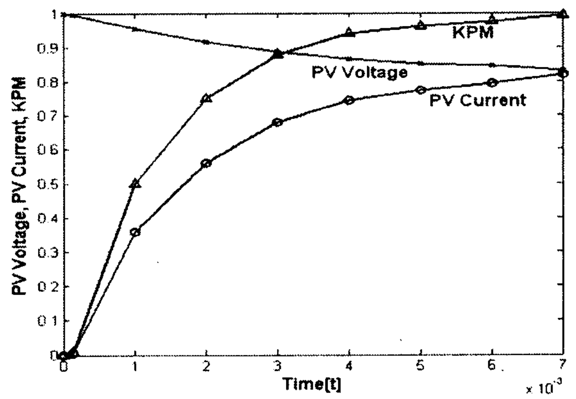

Fig. 7 PV voltage, PV current and K_{PM} where C_d is a 10[mF] until 7ms

2.5 The decision of optimal input capacitor

Simulation results through Fig. 5, 6 and 7 show that if the input capacitor capacitance is large, for example, over 457[μF], K_{PM} can have a value of 1. However, it is needed over 1ms for K_{PM} to reach this value.

Fig. 8 shows the change of K_{PM} due to the change of input capacitor capacitance.

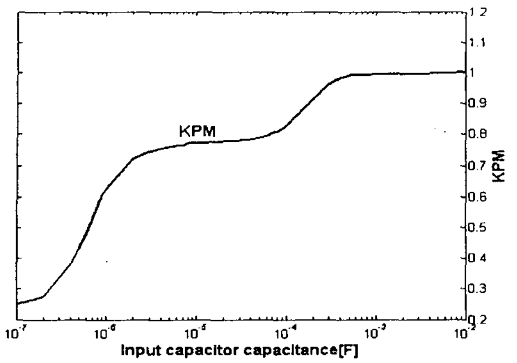

Fig. 8 The relationship between input capacitor capacitance and K_{PM}

2.6 The difference of K_{PM} caused by I-V curve data

Fig. 8 shows a result using only one set of I-V curve data. However, I-V curve data can be plotted by adjusting Voc, Isc and fill factor. Some sets of I-V curve data are selected to know whether there is relationship between input capacity and K_{PM} or not.

Fig. 9 and 10 show the relationship between input capacitor capacitance and using two kinds of I-V curve data. In Fig. 9, Voc is a 293[V], Isc is a 14.9015[A] and fill factor is a 0.7.

In Fig. 10, Voc is a 330(V), Isc is a 11(A) and fill factor is a 0.85.

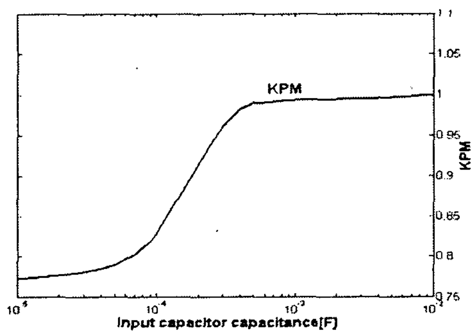

Fig. 9 the relationship between input capacitor capacitance and K_{PM} using fill factor 0.7

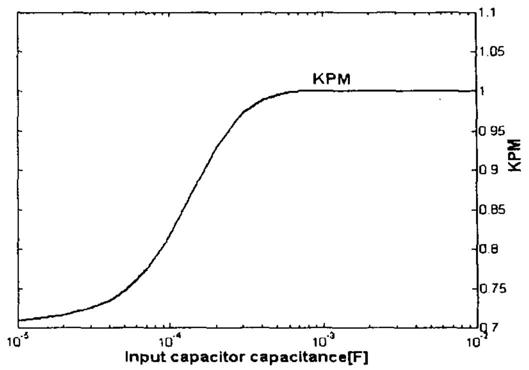

Fig. 10 the relationship between input capacitor capacitance and K_{PM} using fill factor 0.85

Fig. 9, 10 do not show any differences between input capacitor capacitance and when two different I-V curve data are used.

3. Conclusions

In this paper, it proposed a method that the selection of appropriate value of PV inverter is calculated using implicit trapezoidal formula. Generally, if input capacitor has several mF, the efficiency will be 100% so that K_{PM} can have a value of 1. Even if input capacitor has a few hundreds μF, K_{PM} will be have a value of over 0.9.

Regarding of time, if input capacitor capacitance is a several mF, it will take a few ms[milli second] for K_{PM} to reach a value of 1. However, if input capacitor capacitance is a few hundreds μF, it will take less than 1ms for K_{PM} to reach a value of 1.

To sum up, using several hundreds μF capacitor capacitance is better than using a few mF capacitor capacitance. Because input capacitor of several hundreds μF capacitance is cheap, can have a K_{PM} value over 0.9 and needs approximately 1ms to achieve a steady-state compared to input capacitor had a few mF capacitance.

References

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[2] Kosuke Kurokawa "Numerical analysis of the performance of a photovoltaic array curve tracer by the capacitive load method", *Solar Cells*, Vol. 31, 1991.