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Research on Harmonic Suppression of Microgrid Based on Improved Droop Control

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Abstract. Previous harmonic suppression system is generally through the system detection for harmonic content in the system and corresponding harmonic frequency is obtained by active filter unit but in the opposite direction of harmonic signal to offset the harmonic wave of output voltage and current. This paper embarks from the internal system, according to the superposition theorem in the basic of the original, on the basis of improved droop control of a harmonic domain droop control strategy, finally through every harmonic controller output signal and fundamental domain prolaose controller output signal superposition for inverter input signal. This method from harmonic source in order tu reduce the system harmonic content, effectively reduce the use of filter equipment, improve the effiviency of the system, and increase the response speed of the system, to a certain extent, to reduce the harmonic THD has certain significance.

1. Introduction

The main harmonics in the micro grid are derived from the inverter, the harmonic sources in the inverter are mainly two, one is the pulse width modulation device, and the other comes from the. At present, the main load is nonlinear load, when the voltage source to provide sinusoidal voltage will produce harmonic current, the harmonic current in the output voltage of the output impedance of the harmonic component. Among them, odd times three times harmonic (H) called harmonics in H phase system it is called zero sequence harmonic, harmonic called negative sequence harmonic, it will cause the machine to produce reverse torque reversal causing device failure. At present, the electric total harmonic distortion of current and skin THD) need to ensure that within the specified range (less than 5%), the main purpose is to improve the basic droop control, to reduce the harmonic voltage, and the active filter to less harmonic current.

This affects the power distribution through the characteristics of output impedance largely, output impedance characteristics at the same time also play a crucial role in reducing the output voltage of THD, and can reduce the output impedance of the size or the output variable is capacitive anti spy and other means to reduce the voltage THD. This paper mainly through the following steps to reduce the voltage stress THD.

Let a work in grid connected or parallel current source voltage harmonic frequency of the inverter load. On this basis, can be studied separately in each harmonic frequency interval of harmonic voltage, if the output voltage of the inverter is added a large number of harmonic voltage, we can respectively control the voltage THD of different harmonic domain so as to reduce the voltage harmonic.

- A constant pressure constant current source is provided for the droop device. Pressure.
- Establish a harmonic suppression device to reduce the harmonic output voltage. Pressure.
- This method can achieve the purpose of harmonic sharing in each harmonic frequency range, avoid the calculation of active and reactive power in different frequency range, and improve the accuracy of power sharing.

2. Harmonic domain theory analysis pressure droop controller

By superposition theorem, the output current of the current source can be superimposed on the current component in the frequency range. Figure 1 is the mathematical model of the inverter.

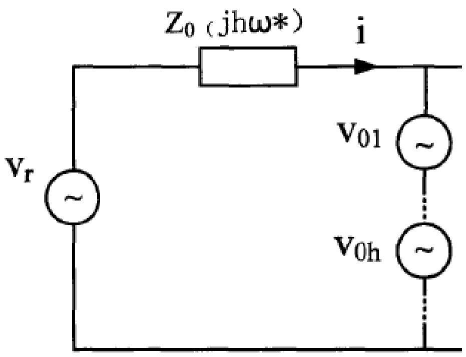

Figure 1. Equivalent physical model of inverter $(jh\omega *)$.

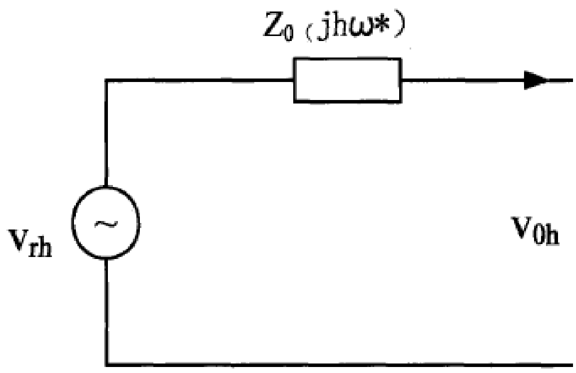

Figure 2. h the equivalent model of the second harmonic of the inverter.

Figure 2 is the mathematical model of the inverter, v_r is the reference voltage, the output impedance is Z_0, as for the load voltage source in series model combined into a current source in parallel, the output voltage of the fundamental voltage and harmonic voltage and is expressed as

$$v_0 = v_{01} + \sum_{h=2}^{\infty} v_{0h} \tag{1}$$

Among them, $v_{01} = \sqrt{2} v_{01} \sin(\omega t)$,

$v_{0h} = \sqrt{2}v_{0h}\sin\left(h\omega t + \varphi_h\right)$, the system refers to the angular frequency is ω. v_{01} is the fundamental component of the voltage, the second harmonic component of the h voltage value is v_{0h}, output or load current can be expressed as

$$i = \sum_{h=1}^{\infty} i_h \tag{2}$$

Among them, $i_h = \sqrt{2}I_h \sin\left(h\omega t + \phi_h\right)\left(jh\omega^*\right)$, the reference voltage v_r is expressed as

$$v_r = v_{r1} + \sum_{h=2}^{\infty} v_{rh} \tag{3}$$

Among them, $v_{r1} = \sqrt{2}E\sin\left(\omega t + \varphi\right)$, $v_{rh} = \sqrt{2}E_h \sin\left(h\omega t + \varphi_h\right)$ often in the inverter droop control system in general we will be regarded E_h as 0, in this section in order to make v_{0h} the trend of nearly 0, we do not see the E_h as the 0 treatment of E_h,

$$E_h = I_h \left| Z_0\left(ih\omega^*\right)\delta_h = \phi_h + < Z_0\left(ih\omega^*\right)\right| \tag{4}$$

By superposition theorem, we decompose the current in each harmonic frequency domain independently.

3. Improved droop controller design pressure harmonic domain

According to the transmission characteristic diagram in Figure 3, the voltage source v_r is transmitted to the current source through impedance $Z_0 < \theta$, the port voltage

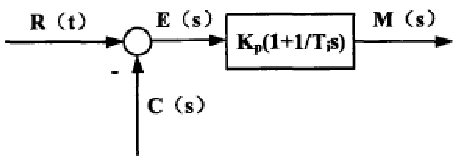

Figure 3. Proportional integral (PI) controller.

$$\begin{aligned} V_0 &= E < \delta - Z_0 I < \theta = E\cos\delta - Z_0 I\cos\theta \\ &+ j\left(E\sin\delta - Z_0 I\sin\theta\right) \end{aligned} \tag{5}$$

The active and reactive power respectively pressure

$$P = E\cos\delta - Z_0 I^2\cos\theta \quad Q = E\sin\delta - Z_0 I^2\sin\theta \tag{6}$$

When the δ pressure is very small

$$P \approx EI - Z_0 I^2\cos\theta \tag{7}$$

$$Q \approx EI - Z_0 I^2 \sin\theta \tag{8}$$

That is: $P : E \quad Q : \delta$

It can be found that the relationship between them will not change because of the output impedance, which is very different from the voltage source. Thus, the control equation of the droop control strategy can be obtained.

$$E_i = E^* - n_i P_i \tag{9}$$

$$\omega_i = \omega^* - n_i Q_i \tag{10}$$

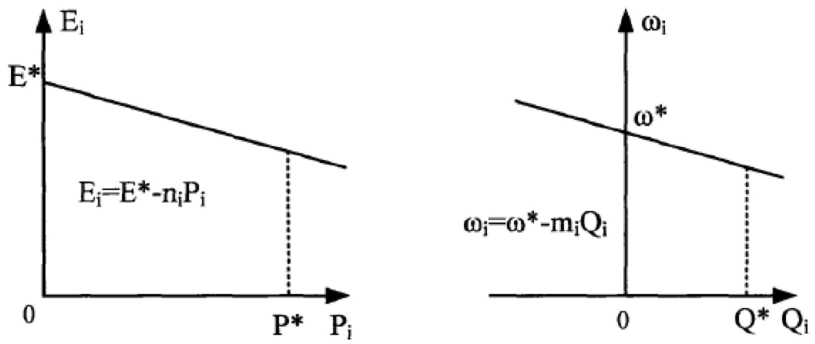

Figure 4. Improved droop characteristic curve.

Figure 4 is the droop characteristic curve of the droop control, it is different from any other droop characteristic curve, here in order to ensure the P-E and $Q-\omega$ rings are negative feedback, need to set the frequency and electric skin value, guarantee $n_i P_i$ and $m_i Q_i$ were negative.

The advantage of the droop control strategy is that the droop controller does not need to change the droop control equation according to the output impedance, which greatly increases the application range of the droop controller. Using this factor, the type of output impedance is not considered in the corresponding harmonic domain. When $E = Z_0 I \quad \delta = \theta$, P=0 Q=0 can be obtained by the combination of (6), we can find that it is (4), another form of expression can also be used to reduce or even eliminate the output voltage harmonics.

The main role is to work in the inverter load standard of active and reactive power and frequency condition, it is the fundamental work in the state of no harmonic, when a plurality of parallel inverter, according to the needs of their own capacity proportional distribution of active and reactive power (also in the fundamental domain), we assume that after impedance harmonic current of Z_0 is equal to the reference voltage i_h compensation amount to send (h harmonic),

Meet the following conditions

$$E_h = I_h \left| Z_0 \left(ih\omega^* \right) \right| \varphi_h = \phi_h + < Z_0 \tag{11}$$

According to the superposition theorem of voltage, the droop controller can also be analyzed independently in different frequency domain. This section mainly through the injection of harmonic voltage in the output voltage to reduce the harmonic components of voltage, according to the previous discussion, in order to h second harmonic component to the voltage of the 0 (close to), then graph (b) of the voltage source v_{oh} needs 0, is passed to the current source is i_{oh} reactive power and reactive power is zero. The ideal state of the droop voltage of the droop controller at h is required to be zero. The frequency setting should be set to the h harmonic frequency, so we can get the droop control equation of the h harmonic

$$E_h = -n_h P_h \tag{12}$$

$$\omega_h = h\omega - m_h Q_h \tag{13}$$

Where P_h and Q_h are expressed in the H frequency domain harmonic active and reactive components, m_h and n_h respectively in the frequency domain of each coefficient, (here, mainly through the yang to the value of the number of harmonic response) we can get h harmonic domain droop controller, as shown in Figure 5 show.

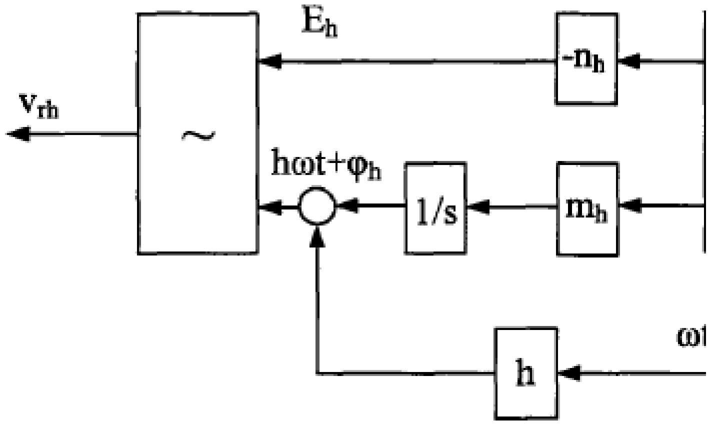

Figure 5. 28th sub harmonic droop controller.

The droop controller does not vary according to the nature of the output impedance, whether it is resistive, inductive or capacitive. By formula (12) shows that it is a proportional controller, there will exist a static error and V_{0h} is not zero (just close to zero) V_{0h} can approximate the pressure.

$$v_{0h} \approx E_h - I_h \left| jh\omega Z_0 \right| I_h \approx -n_h V_{0h} I_h - \left| jh\omega Z_0 \right| I_h \tag{14}$$

$$v_{0h} \approx -\frac{\left| jh\omega Z_0 \right| I_h}{n_h I_h + 1} \tag{15}$$

The voltage THD can be approximated by the formula of V_{oh}/E, we can know that in H harmonic frequency, output were minor resistance would cause the voltage of THD is smaller, the choice of droop coefficient n_h is larger so as to reduce the V_{oh} of the stability of system, which is the basic principle of harmonic suppression in sine wave in n_h, can be expressed as

$$n_h \approx -\frac{|jh\omega Z_0|}{\Upsilon E} \tag{16}$$

The Υ represents the compensation value of THD in the h harmonic frequency domain. Once the system is unstable, it is necessary to reduce the value of Υ in the frequency domain $(m_h Q_h)/h\omega$ of the h harmonic, so m_h can be calculated as follows

$$m_h \approx m_1 \frac{hQ}{Q_h} \tag{17}$$

It is not difficult to find, because hQ is much larger than Q_h, so the value of m_h is much greater than m_1. In order to reduce the harmonics in the output voltage, the voltage droop controller generates the essence can be regarded as the fundamental domain and frequency domain harmonic voltage droop controller is generated and, as of 18 pressure

$$v_r = v_{ri} + \sum_{h=2}^{\infty} v_{rh} \tag{18}$$

In the design of the droop controller, we can get the principle block diagram of the improved droop controller which has the function of accurate power distribution and harmonic suppression. As shown in Figure 6.

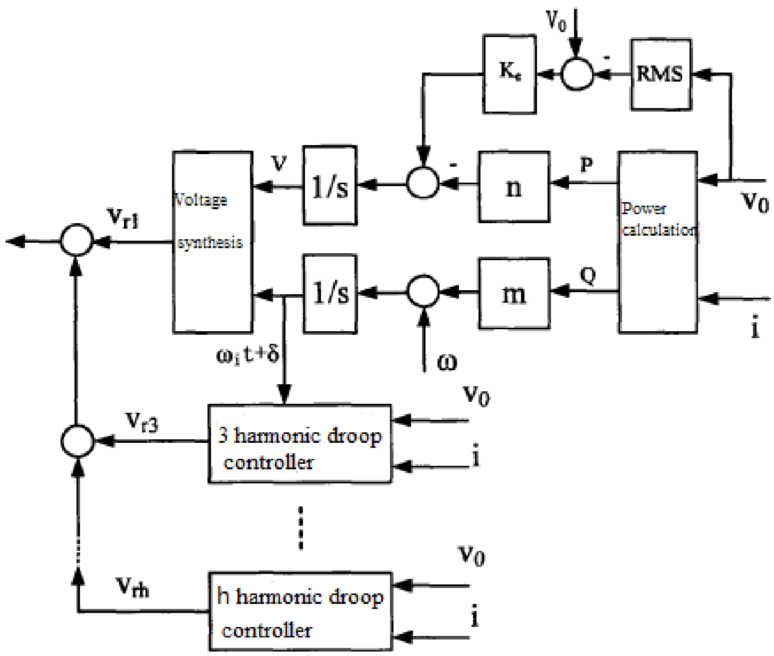

Figure 6. Harmonic frequency droop controller schematic.

4. Simulation of pressure

Based on two parallel inverter system Matlab platform, the capacity ratio of 1 to 2, according to the principle of frequency domain above the control chart, in combination with the relevant parameters in the previous section in droop control and the following parameters, operating conditions of the simulation for island mode operation. Due to the limited conditions, the simulation is only built to the 7 harmonic controller models. As shown in Figure 7.

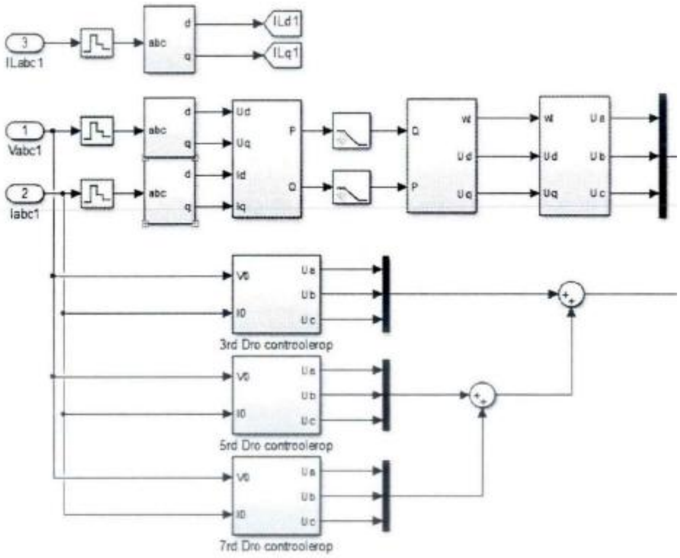

Figure 7. Simulation model based on improved droop harmonic suppression controller.

The Matlab simulation software platform is used to establish two micro power supply parallel system, the micro power supply is replaced by the DC voltage source, the DC side voltage source voltage of the inverter is 350V, and the output end adopts the passive LC filter device. Two the inverter capacity is equal, the simulation is based on the island mode operation, divided into pressure.

One condition:

Only the improved droop controller is used to parallel the two inverters. Figure 8, Figure 10 (a) and Figure 10 (b) are the output current waveform and harmonic content. Pressure

Condition two:

By using the frequency domain harmonic droop controller (3, 5, 7), the two inverters parallel operation, Figure 9, Figure 10 (b) and Figure 11 (b) respectively for the case of output voltage and current waveform and harmonic content. As shown in Table 1.

Table 1. Simulation parameters of improved droop controller.

	1 inverter	2 inverter
LC Filter parameters	L=3.9mH	L=2.11mH
	C=29uF	C=27uF
K_i (Virtual impedance)	K_{i1}=5	K_{i2}=3
Fundamental domain	m11=7.66×10^{-4}	M21=3.67×10^{-4}
	n11=0.04595	n21=0.2698
Three harmonic field	m13=0.0325	M23=0.0169
	n13=2.7	n23=1.35
Five harmonic field	m15=0.0325	M25=0.0169
	n17=2.7	n25=1.35
Severn harmonic field	m17=0.33625	M27=0.00169
	n17=5.4	n27=2.7

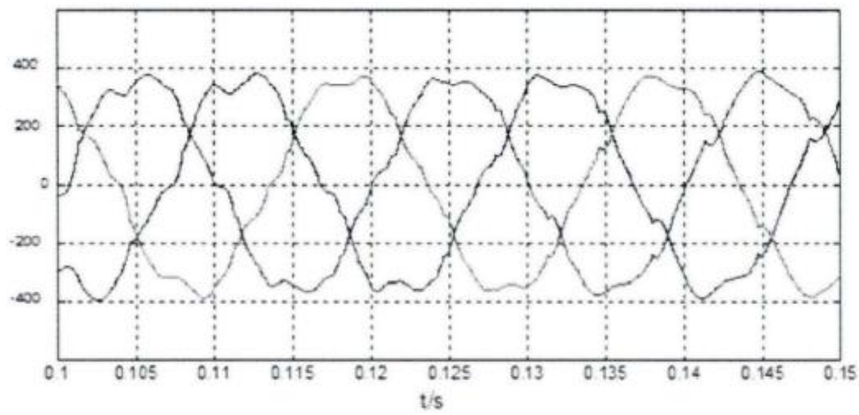

Figure 8. Output l voltage waveform of working condition.

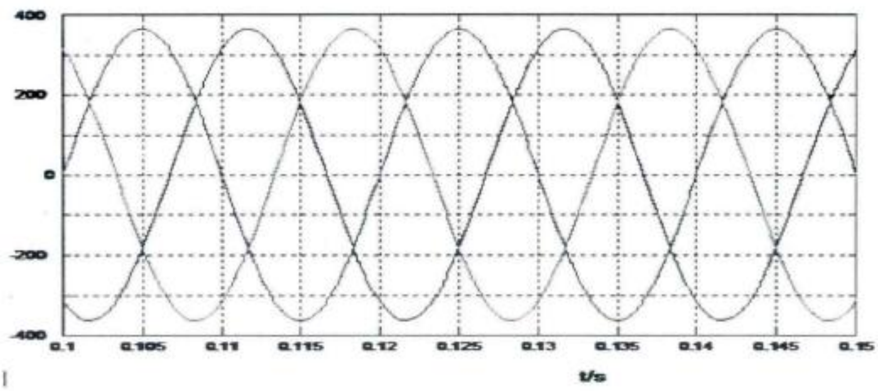

Figure 9. Output2 voltage waveform of working condition.

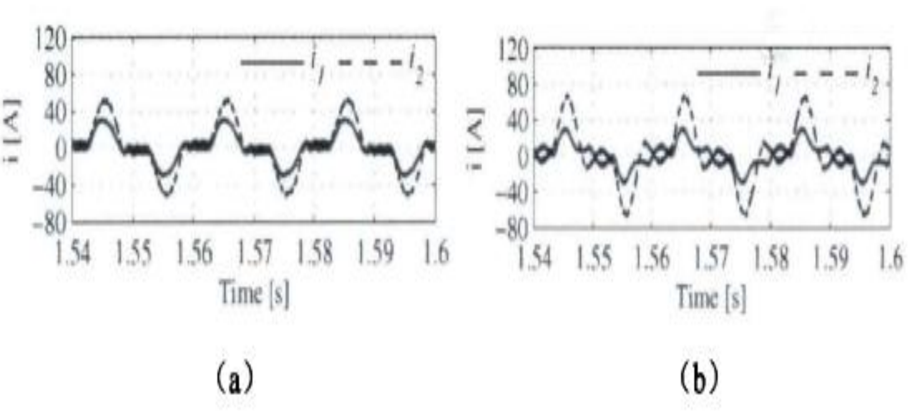

Figure 10. Output single phase current (a).working condition 1 (b) working condition 2.

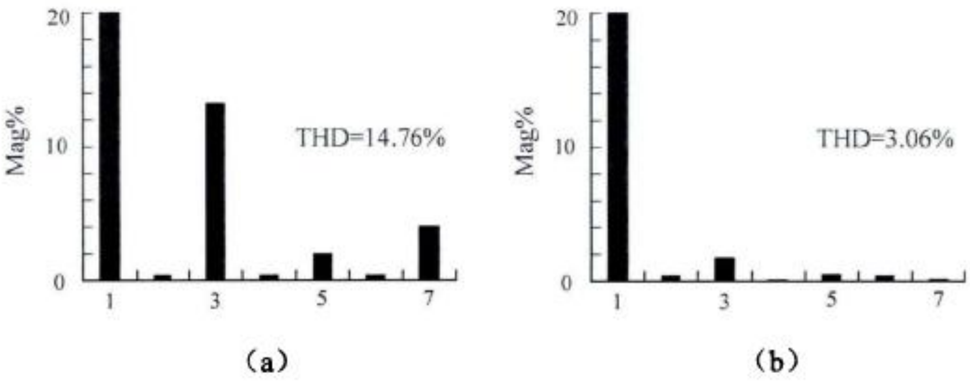

Figure11. Each harmonic content (a) working condition 1 (b) working condition 2.

Compared with Figure 8 and 9, it is found that the harmonic content of the output voltage is significantly reduced, and the output voltage waveform is smooth and smooth in the condition of the working condition of 2. Fig. 11 (a) (b) two harmonic content, can be found in the droop controller of each harmonic domain, the harmonics in the output voltage has been significantly reduced, and the THD from 14.76% to 1 of the cases decreased to 3.06% in 2 cases, satisfy the micro grid of harmonic less than 5% of the provisions of THD wave.

The above image simulation shows that by adding the active droop controller for each harmonic reactive power respectively control the way in harmonic domain, the harmonic suppression of the micro grid has significant effect, and use the method of micro power after the voltage and current output power quality have been optimized obviously the harmonic component and its output has also been inhibited. The harmonic distortion rate has greatly decreased. It can be seen that the frequency domain droop control strategy in the harmonic domain is worthy of recognition.

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