



Research on Multi-master-slave Hybrid Coordinated Control Method in VANET Environment

Chao Song^(✉)

Dalian University of Science and Technology, Dalian, China
lxyh201712@163.com

Abstract. To improve the quality and output efficiency of multi-master-slave hybrid operation, a coordinated control technology of multi-master-slave hybrid operation based on closed-loop error regulation in VANET environment is proposed. The constraint parameter model of multi-master-slave hybrid coordinated control is constructed, and the DC voltage stabilizing capacitance, DC voltage outer loop gain, interharmonic oscillation and electromagnetic loss are taken as the constraint parameters. An input-output closed-loop control system for multi-master-slave hybrid operation of power grid is constructed, and the internal loop feedback adjustment method is used to compensate the interharmonic output error. The steady state regulation method of open circuit voltage and short circuit current is used to realize the adaptive identification of control constraint parameters, and the coordinated control of multi-master-slave hybrid operation of power grid is realized. The simulation results show that this method can effectively realize the multi-master-slave coordinated control in VANET environment, increase the output efficiency of the power grid, and improve the output quality and gain of the power grid control.

Keywords: VANET environment · Power grid · Multi-master-slave mixing · Coordinated control

1 Introduction

With the development of large power grid distribution network technology, the scale of power grid in our country is increasing. Through the mixed operation of multi-master-slave power grid, all-weather, large area and fully covered power supply can be realized, and in the multi-master-slave hybrid operation of power grid [1]. The high voltage power supply and multi-terminal input and output control methods are used for power input and distribution, and the optimized multi-master-slave hybrid coordinated control method is used for the output power regulation and node distributed design of the power grid, so as to improve the output efficiency of the power grid. Reduce the power loss and promote the energy saving and efficiency of the multi-master-slave hybrid operation of the power grid. It is of great significance to study the coordinated control technology of multi-master-slave hybrid operation in order to improve the operation stability of power grid and the gain of DC voltage outer loop, and to reduce the power loss. The research of related control technology has attracted great attention [2].

The research on energy saving, quality improvement and efficiency control technology of power grid distribution network is based on the optimal configuration and adaptive adjustment of power grid parameters. The multi-master-slave hybrid operation of power grid is affected by small disturbance and output steady-state error. As a result, the stability of the control is not high. The optimization of control technology was studied in the relevant literature. In reference [3], a multi-master-slave hybrid coordinated control method based on fuzzy PID control technology is proposed. The proportional resonance control technology is used to optimize and adjust the parameters of multi-master-slave hybrid operation to improve the output voltage gain and power gain, but the control algorithm can not effectively suppress the small disturbance interference, and the steady-state error of the control output is high. In reference [4], a coordinated control technology of multi-master-slave hybrid operation based on adaptive feedback regulation is proposed. The inertia link is used for analog output compensation control, and the differential evolution method is combined with the energy saving control of the power grid to improve the control stability. However, the computational overhead of this method is large and the real-time control is not good.

In order to solve the above problems, a coordinated control technology of multi-master-slave hybrid operation based on closed-loop error regulation in VANET environment is proposed in this paper. The constraint parameter model of multi-master-slave hybrid coordinated control is constructed, and the DC voltage stabilizing capacitance, DC voltage outer loop gain, interharmonic oscillation and electromagnetic loss are taken as the constraint parameters. An input-output closed-loop control system for multi-master-slave hybrid operation of power grid is constructed, and the internal loop feedback adjustment method is used to compensate the inter-harmonic output error. The steady state regulation method of open circuit voltage and short circuit current is used to realize the adaptive identification of the control constraint parameters and the control optimization is realized. Finally, the simulation experiment is carried out. The advantages of this method in improving the coordinated control performance of multi-master-slave hybrid operation are shown.

2 Multi-master-slave Hybrid Operation Modeling and Controlled Object Description of Power Grid

2.1 Analysis of Control and Confined Parameters for Multi-master and Master-Slave Hybrid Operation of Power Grid

In the multi-master-slave hybrid operation of the power grid, the DC/AC inverter model is mainly used to stabilize the voltage transmission and power output control, and the inner loop control model is used to construct the controlled object model of the multi-master-slave hybrid coordinated control of the power grid [5]. In order to realize the optimal control of multi-master-slave hybrid operation, the constrained parameter model of power grid control is analyzed. The output power coefficient of power grid in multi-master-slave hybrid operation is k_f , and the power modulation coefficient of voltage distribution in power grid is B_r . The magnetic density of the controller permanent magnet is as follows:

$$B_g = \frac{F_m}{A_g \mathfrak{R}} \tag{1}$$

Wherein, F_m is the three-phase current base on the grid side, A_g is the additional DC voltage stabilizing capacitance, \mathfrak{R} is the DC voltage outer loop gain of the power grid, and when the power grid is in the steady state, the DC voltage stabilizing capacitance and the DC voltage outer loop gain of the power grid are taken as the DC voltage stabilizing capacitance and the DC voltage outer loop gain of the power grid. The interharmonic oscillations and electromagnetic losses are constraint parameters, and each constraint parameter can be estimated as follows:

$$F_m = \frac{B_r l_m}{\mu_0 \mu_{r1}} \tag{2}$$

$$A_g = l_s \frac{\beta \pi}{p} (r_r + l_g) \tag{3}$$

The DC voltage stabilizing capacitance and electromagnetic loss are added to the grid side, and the PI control method is used to describe the output electromagnetic gain in the d, q axis distributed at the distribution network nodes.

$$\mathfrak{R} = \frac{1}{\mu_0 l_s \beta \pi / p} \left(\frac{1}{\mu_{r1}} \int_{r_r - l_m}^{r_r} \frac{d_r}{r} + \int_{r_r}^{r_r + l_g} \frac{d_r}{r} + \frac{1}{\mu_{r2}} \int_{r_r + l_g}^{r_r + l_g + l_w} \frac{d_r}{r} \right) \tag{4}$$

The vacuum permeability $\mu_0 = 4\pi \times 10^{-7}$, μ_{r1} and μ_{r2} of the multi-master-slave hybrid operation of the power grid represent the transmission loss and output efficiency of the multi-master-slave hybrid operation of the power grid. When the power grid is in the steady-state operation state of the whole network, the steady-state error is introduced [6]. The distribution of control constraint parameters for multi-master-slave hybrid operation of power grid is obtained as follows:

$$L_x = (1 - k_2)L_{11} \tag{5}$$

$$L_{mx} = k^2 L_{11} \tag{6}$$

$$n_x = k \sqrt{\frac{L_{11}}{L_{22}}} \tag{7}$$

The power loss of the distribution network running at the resonance point is as follows:

$$B_g = \frac{B_r l_m}{(r_r + l_g) \ln\left(\frac{r_r + l_g + l_w}{r_r - l_m}\right)} \tag{8}$$

Considering the influence of magnetic flux leakage coefficient k_1 and current loop k_β , energy saving compensation control is carried out by adaptive feedback adjustment. Through the above analysis, the constraint parameter model of coordinated control of multi-master-slave hybrid operation of power grid is constructed, which provides the model constraint conditions for the design of control algorithm [7].

2.2 Description of the Controlled Object

On the basis of the above control constraint parameter model, the DC/AC inverter model is used to construct the input and output network structure model of multi-master-slave hybrid operation, as shown in Fig. 1.

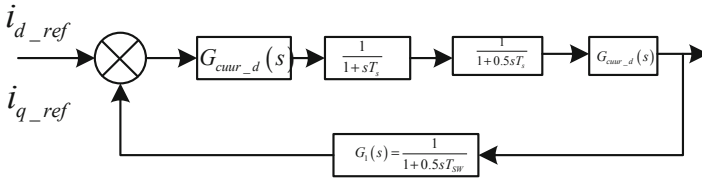


Fig. 1. Input and output structure block diagram of multi-master-slave hybrid operation in power grid

According to the input and output model given in Fig. 1, the controlled object model of multi-master-slave hybrid operation of power grid is constructed. T_s is used to represent the sampling time of current parameters in distribution network, and $\frac{1}{1+sT_s}$ is used to represent the control delay of multi-master-slave hybrid operation of power grid. i_{d_ref} represents the reference values of active current and reactive current in multi-master-slave hybrid operation of power grid, respectively. L_s represents the inductance on the grid side, $G_{cuur_d}(s)$, $G_{cuur_q}(s)$ indicate the current component of the inner loop operating grid on the d, Q axis, GS indicates the winding size, and R represents the current component of the inner ring operating on the d, q axis. i_{d_ref} is used to describe the power gain of d axis and q axis in multi-master-slave hybrid operation of power grid. Under the condition of small disturbance [8], the output torque and gain adjustment coefficient of the controller are expressed as follows:

$$T_{em} = \frac{\pi k_f k_c k_1 k_\beta B_r l_m l_s l_w (2r_r + 2l_g + l_w) J_{cu}}{\ln\left(\frac{r_r + l_g + l_w}{r_r - l_m}\right)} \tag{9}$$

$$k_1 = 1 - \frac{1}{0.9[r_r / (\beta p (l_g + l_w))]^2 + 1} \tag{10}$$

Based on the analysis of the constraint parameters of the above large electrical equipment controller and the description of the controlled object, the modulation gain

system function of the inner loop control of the multi-master-slave hybrid operation of the power grid is obtained as follows:

$$G_1(s) = \frac{1}{1 + 0.5sT_{SW}} \tag{11}$$

Wherein, s represents the reference voltage and I_{sd_ref} represents the current component on the outer loop of the distribution network, $T_{SW} = 1/f_{SW}$, the control object of improving quality and increasing efficiency in multi-master-slave hybrid operation of power grid is constructed, and the control optimization by parameter adjustment and model identification is realized [9].

3 Control Algorithm Optimization

On the basis of the above construction of the constrained parameter model and the controlled object model of the multi-master-slave hybrid coordinated control of the power grid, the optimal design of the distribution network control is carried out. In this paper, a coordinated control technology of multi-master-slave hybrid operation based on closed-loop error regulation in VANET environment is proposed [10]. The equivalent circuit model of multi-master-slave hybrid operation of power network is constructed by using T-type equivalent circuit analysis method, as shown in Fig. 2.

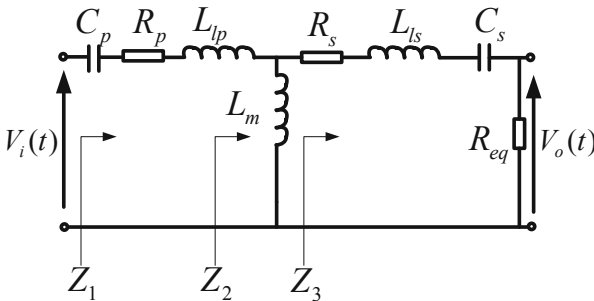


Fig. 2. Equivalent circuit model

According to the equivalent circuit model given in Fig. 2, an input-output closed-loop control system for multi-master-slave hybrid operation of power grid is constructed, and the output voltage $E = vl \times B$ of power grid is assumed. If the instantaneous current $v = r\omega_r$ and resistance are $r = r_r + l_g$, power factor $B = k_\beta k_1 B_g$, induction inductor $l = l_s k_f k_c A_w / A_c$, the energy function of multi-master-slave hybrid operation of power grid is as follows:

$$E = \frac{(r_r + l_g)k_\beta k_1 B_g \omega_r l_s k_f k_c A_w}{A_c} \tag{12}$$

The internal loop feedback adjustment method is used to compensate the inter-harmonic output error [11], and the parameter adjustment function is described as follows:

$$G_{curr_d}(s) = \frac{K_{P1}s + K_{11}}{sG_1(s)} \tag{13}$$

$$G_{curr_q}(s) = \frac{K_{P2}s + K_{12}}{sG_1(s)} \tag{14}$$

Wherein, K_{P1} , K_{11} , K_{P2} , K_{12} are used to describe the dq axis components of the output current adjusted by steady state in the process of multi-master-slave hybrid operation. Because the controller parameter K_{P1} , K_{11} , K_{P2} , K_{12} are unknown, according to the Lyapunov functional, the steady-state error convergence value of multi-master-slave hybrid operation of power grid satisfies $\begin{bmatrix} Y_{11} & Y_{12} \\ Y_{12}^T & Y_{22} \end{bmatrix} \geq 0, N = \begin{bmatrix} N_1 \\ N_2 \end{bmatrix}, M = \begin{bmatrix} M_1 \\ M_2 \end{bmatrix}$, under the constraint of model parameters. The fitness function of improving quality and increasing efficiency in multi-master-slave hybrid operation of power grid can be described as follows:

$$F_{inner_dq} = \sum_{k=1}^M F|i_{dq}(k) - i_{dq_cal}(k)| \tag{15}$$

Similarly, by using the steady state regulation of open circuit voltage and short circuit current [12], the fitness function of the outer loop controller with multi-master-slave hybrid operation can be described as follows:

$$F_{outer_dq} = \sum_{k=1}^M F|i_d(k) - i_{d_cal}(k)| \tag{16}$$

The i_{dq} represents the gain of the inertia phase, and finally the objective function of the coordinated control of the multi-master and slave hybrid operation of the power grid can be described as:

$$F = \sum_{k=1}^M |e(k)|G_{eq}(s) \tag{17}$$

Wherein, $G_{eq}(s)$ is the constraint function of three-phase control on the parallel side. Based on the above treatment, the steady-state regulation method of open-circuit

voltage and short-circuit current is used to realize the adaptive identification of the control constraint parameters. The coordinated control of multi-master-slave hybrid operation of power network is realized.

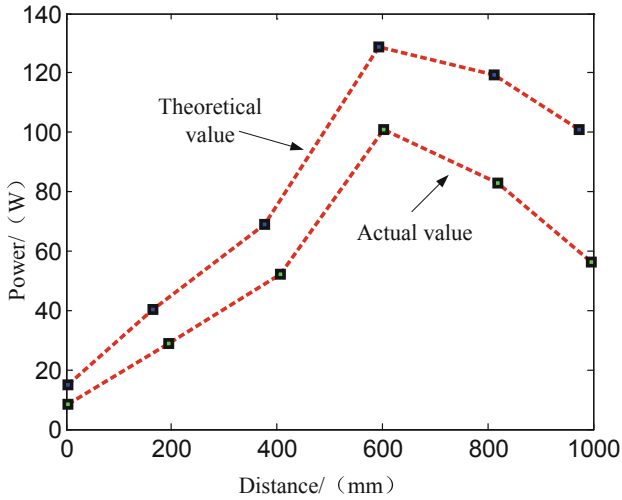
4 Simulation Experiment and Performance Analysis

In order to test the application performance of the method to improve the quality and efficiency control in the multi-master and slave hybrid operation of the power grid, the simulation experiment is carried out, the experimental software platform is established on the MATLAB 7.0, the value of the permanent magnetic density of the distribution network transmission is between 1.2 and 2.3, the initial value of the electric loss is 1.24 Kw/h, The torque output of the multi-master-slave hybrid operation of the power grid is 10 N.m, the distance of the distribution network transmission coil is increased from 50 to 100 cm, the magnetic resonance resistance of the distribution network coil is SF, and the frequency of the voltage conversion is $R_{p1} = 45 \Omega$, $f = 27.05 \text{ MHz}$, $C_r = 14.6 \text{ pF}$, $R_o = 30 \Omega$ and the output of the optimized control variable is shown in Table 1.

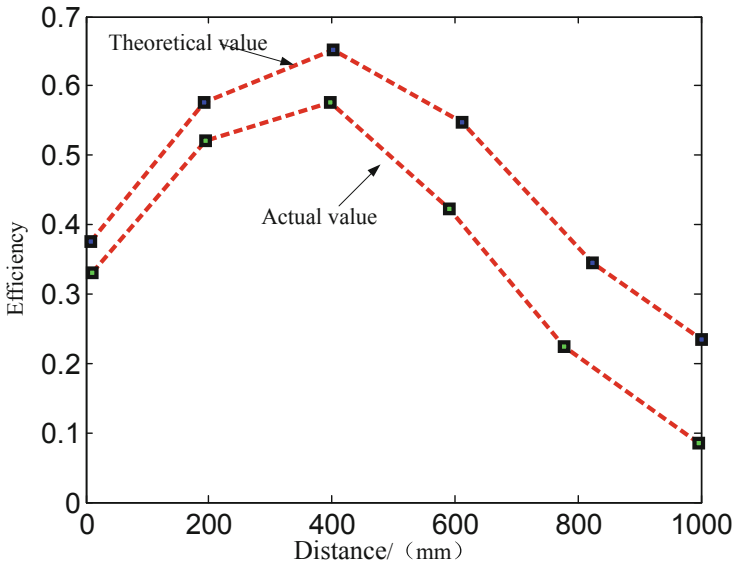
Table 1. Optimal control variables for efficiency control of multi-master-slave hybrid operation system in power grid

Variable name	Lower limit	Superior limit	Optimization result
p	2	6	4
β	0.34	0.67	0.42
$l_m(m)$	0.045	0.065	0.053
$l_y(m)$	0.034	0.089	0.046
$l_w(m)$	0.043	0.065	0.087
$l_g(m)$	0.013	0.026	0.057
$r_r(m)$	0.021	0.134	0.323
λ	0.312	0.123	2.53
A_c	0.523	1	2.0

According to the above control parameter optimization design, the power grid multi-slave hybrid coordination control benefit analysis is carried out, the output power and the efficiency of the power grid are tested, and the results are as shown in Fig. 3.



(a) Power test of multi-master-slave hybrid operation in power grid



(b) Efficiency test of multi-master-slave hybrid operation in power grid

Fig. 3. Multi-master-slave hybrid operation of power grid

The analysis of Fig. 3 shows that the proposed method has good output power, high efficiency and good tracking and matching effect between the actual value and the theoretical value, which shows that the proposed method has a good performance of improving quality and increasing efficiency. By comparing different methods, the

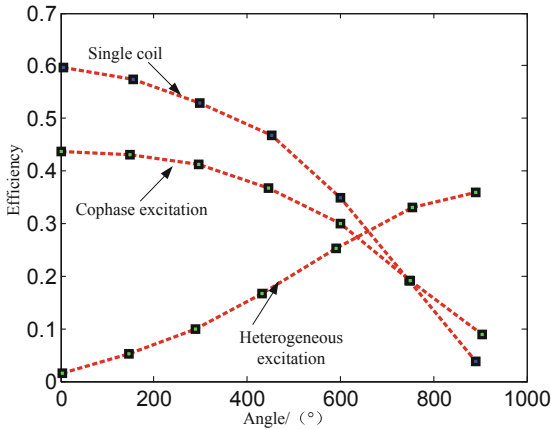


Fig. 4. Control performance comparison test

results of control performance comparison are shown in Fig. 4. Analysis of Fig. 4 shows that the proposed method achieves multi-master-slave hybrid coordinated control of power grid, and the output quality of parameters is high, which improves the output efficiency of power grid. It shows that the control quality of the proposed method is high.

5 Conclusions

In the multi-master-slave hybrid operation of the power grid, the high-voltage power supply and multi-terminal input and output control methods are used for power input and distribution, and the steady-state error of voltage output is affected by the multi-master-slave hybrid operation of the power grid. In order to improve the quality and output efficiency of multi-master-slave hybrid operation, a coordinated control technology of multi-master-slave hybrid operation based on closed-loop error regulation in VANET environment is proposed in this paper. The control constraint parameters are analyzed, and the input and output closed loop control system of multi-master-slave hybrid operation is constructed. The internal loop feedback adjustment method is used to compensate the inter-harmonic output error, and the coordinated control of multi-master-slave hybrid operation of power grid is realized. Increase DC voltage outer loop gain and output voltage. The research results show that the multi-master-slave hybrid coordinated control of power grid is carried out in this paper, and the output quality of parameters is high, which increases the output efficiency of power grid and improves the quality of power grid control, so it has good application value.

References

1. Seo, D.W., Lee, J.H., Lee, H.S.: Optimal coupling to achieve maximum output power in a WPT system. *IEEE Trans. Power Electron.* **31**(6), 3994–3998 (2016)
2. Liang, S., Hu, X., Zhang, D., et al.: Probabilistic models based evaluation method for capacity credit of photovoltaic generation. *Autom. Electric Power Syst.* **36**(13), 32–37 (2012)
3. Wang, Q., Dong, W., Yang, L.: A wind power/photovoltaic typical scenario set generation algorithm based on Wasserstein distance metric and revised K-medoids cluster. *Proc. CSEE* **35**(11), 2654–2661 (2015)
4. Liu, J., Luo, X.: Short-term optimal environmental economic hydrothermal scheduling based on handling complicated constraints of multi-chain cascaded hydropower station. *Proc. CSEE* **32**(14), 27–35 (2012)
5. Lin, D., Zang, M.: Research on impact fracture behavior of the laminated glass based on cohesive zone model. *J. Mech. Eng.* **53**(22), 176–181 (2017)
6. Chen, S., Zang, M., Xu, W.: A three-dimensional computational framework for impact fracture analysis of automotive laminated glass. *Comput. Methods Appl. Mech. Eng.* **294**, 72–99 (2015)
7. Mujumdar, A., Tamhane, B., Kuroda, S.: Observer-based sliding mode control for a class of noncommensurate fractional-order systems. *IEEE/ASME Trans. Mechatron.* **20**(5), 2504–2512 (2015)
8. Aten, Q.T., Zirbel, S.A., Jensen, B.D., et al.: A numerical method for position analysis of compliant mechanisms with more degrees of freedom than inputs. *J. Mech. Des.* **133**(6), 491–502 (2010)
9. Zhong, F., Li, H., Zhong, S., et al.: An SOC estimation approach based on adaptive sliding mode observer and fractional order equivalent circuit model for lithium-ion batteries. *Commun. Nonlinear Sci. Numer. Simul.* **24**(3), 127–144 (2015)
10. Aguila-Camacho, N., Duarte-Mermoud, M.A., Gallegos, J.A.: Lyapunov functions for fractional order systems. *Commun. Nonlinear Sci. Numer. Simul.* **19**(9), 2951–2957 (2014)
11. Li, Y.F., Fu, R.D., Jin, W., et al.: Image super-resolution using multi-channel convolution. *J. Image Graph.* **22**(12), 1690–1700 (2017)
12. Sun, X., Li, X.G., Li, J.F., et al.: Review on deep learning based image super-resolution restoration algorithms. *Acta Automatica Sinica* **43**(5), 697–709 (2017)