Electric Energy Metering Mechanism Based on Opportunistic Electromagnetic Coupling and Big Data Resonant Cavity with Network Scheduling

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Abstract —Large scale electric energy measurement has the problems of big scale of data, difficult of network scheduling and low measurement accuracy. In order to solve the above problems, this paper proposed the electric energy measurement mechanism based on the electromagnetic coupling system and the big data resonant cavity. Firstly, based on the opportunity coupling mechanism, the electromagnetic opportunity structure and the opportunity control parameters, the electric energy metering opportunity electromagnetic coupling system is constructed. The system has the ability to improve the working efficiency and the energy efficiency of the electromagnetic coupling system. Secondly, the influence of the power transmission network on the electric energy measurement is further eliminated by constructing a resonant cavity based on big data and using the near field opportunity. Finally, to the circuit quality factor of the big data resonant cavity could be obtained based on the combination between capacitance of the capacitor and the parallel diode and the opportunistic electromagnetic coupling system. The experimental results show that, compared with the current transformer ratio test instrument, the proposed algorithm has the advantages of high real-time, high precision and high efficiency etc.

Index Terms—Electric energy metering, opportunistic electromagnetic coupling, big data resonant cavity, network scheduling

I. Introduction

Electric energy measurement is the key technology to ensure the safety and energy saving of power network [1]. By electric energy measurement can enhance the overall efficiency of the economy and the protection of the residents of the normal life of [2] has an important significance. Electric energy measurement has gradually become the key problem of power quality detection [3] and analysis. In order to improve the utilization of electric energy and ensure the quality of power [4], an efficient solution for big data electric energy metering is found. About electric energy measurement, the authors of article [5] presented a high-voltage electrical energy meter comprised of signal sensors, two measurement units, a synthesis unit, power supplies, and extended communication devices. The centralized energy theft detection algorithm utilizing the Kalman filter and a privacy-preserving energy theft detection algorithm were proposed in article [6]. a self-powered battery less Electric potential wireless sensor was presented by Konstantopoulos C *et al*. [7], which harvests near-maximum energy from the plant itself and transmits the Electric potential signal tens of meters away with a single switch, based on inherently low-cost and low-power biostatic scatter radio principles. Jose R T N *et al*. [8] proposed an Automatic Meter Reading system using Unmanned Aerial Vehicles. In article [9], a novel energy management approach for smart homes that combines a wireless network was proposed based on Bluetooth low energy, for communication among home appliances, with a home energy management scheme.

About power quality, the methodology for calculus and manages of the indicators of power quality through the identification and quantification of electromagnetic disturbances was developed by Ando Junior O H et.al [10]. The new segmentation algorithm of voltage waveforms was presented and implemented a strategy of adaptive thresholding to adapt to noisy signals [11]. Hu S et.al [12] presented an integrated hybrid railway power quality control system to deal with the power quality problems in the electrical railway.

On electromagnetic coupling and resonant cavity, Xiao J K *et al*. [13] proposed the high selective band pass filters using end-connected conductor-backed coplanar waveguide and the electromagnetic couplings. In article [14], the author researched the resonant cavity-enhanced multicolor polarization sensitive quantum dot infrared photo detector. The opportunistic embedded architecture was proposed for power network measurement to improve the intelligent degree and robustness optimization of power grid management system [15]. The opportunistic control of electromagnetic coupling may improve the performance and how to design the resonant cavity to satisfy the big data service is a key issue.

The rest of the paper is organized as follows. Section 2 describes the electromagnetic coupling system. We give the electric energy measurement for network scheduling of big data resonant cavities in Section 3. In Section 4,

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the fusion algorithm analysis and verification was completed. Finally, the paper was concluded in Section 5.

II. Electromagnetic Coupling System

The electric energy measurement opportunity electromagnetic coupling system includes the following three parts. They are the opportunistic coupling mechanism, the electromagnetic opportunity structure, and the parameters of opportunistic control. In the opportunistic coupling structure, according to the diversity requirement of the electromagnetic coupling system, the power supply of the coil is used in different sizes, materials and styles. The opportunistic selection of the coil is based on the following conditions.

1. Linear coil can be accurately protect the maximum output power of the coupling system based on the coil material

2. The combination structure of the linear coil and the ring coil can choose the coupling distance and the maximum of the electric energy region according to the distance between the measuring distance and the distance.

3. The combination structure of the rectangular coil and the ring coil can adjust the coil size and mutual inductance according to the measuring distance and the coil turn number.

According to the above opportunistic basis, the coupling mechanism is completed. Based on the combination of electric coupling measurement system of the angular frequency, the dynamic excitation current, input power and the coupling energy loss in long distance transmission, the electromagnetic coupling structure of transformer coil distance, electromagnetic alternating efficiency, the coil number and package type would be determined.

The design of opportunity coupling mechanism and electromagnetic opportunity structure is used to satisfy the linear control characteristics of the electromagnetic coupling system. On the basis of the above, the adaptive control parameters are used to improve the efficiency of the electromagnetic coupling system and the energy efficiency of the system. Based on the above three opportunistic modules, we design an opportunistic electromagnetic coupling system to solve the analysis process, as shown in Fig. 1. This process can solve the problem of dynamic radio energy measurement analysis and diversity measurement.

There are some external disturbance and dynamic change factors of the electromagnetic coupling system in the electric energy measurement. In order to satisfy the demands of electric energy measurement system and ensure the result accuracy of electric energy measurement, the system can optimize the opportunistic control parameters. The local optimization of the opportunistic control parameters can make the electric energy measurement process of the opportunistic electromagnetic coupling mechanism to be reasonable and intelligent. In addition, the combination of the local optimization results and the opportunistic control parameters can effectively improve the efficiency of the system and reduce the energy consumption of the system.

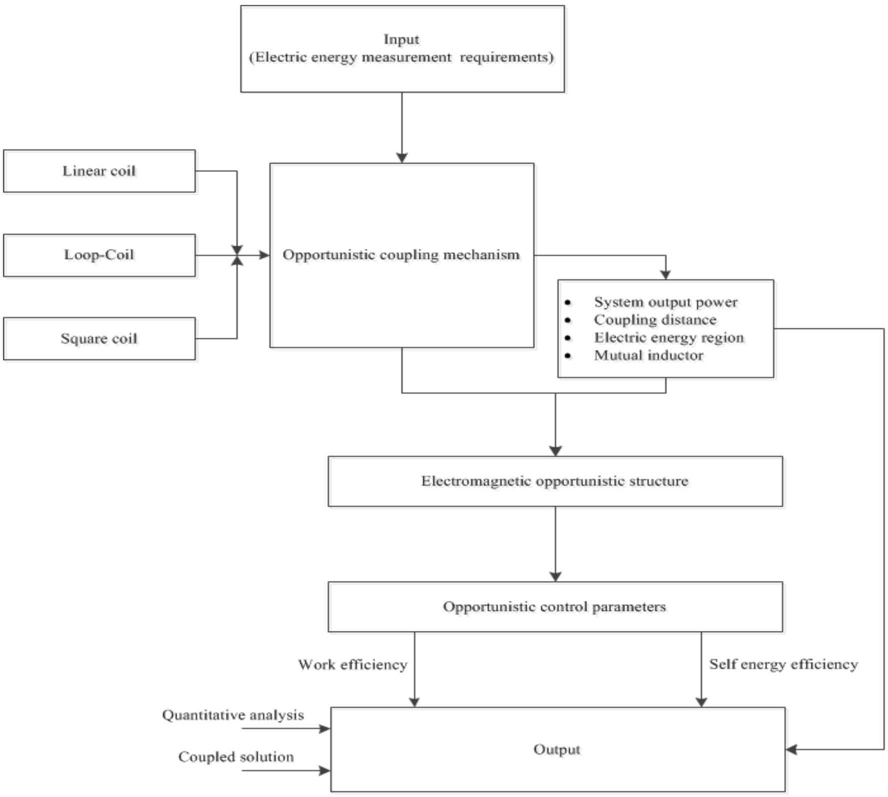

Fig. 1. Solution analysis process of opportunistic electromagnetic coupling system.

In the local optimization process of opportunistic control parameters, the electrical characteristics of the electric energy metering system may generate the unknown changes because of the diversity coil structure and package style. Therefore, in the external interface of opportunity electromagnetic coupling system adds assimilation opportunities for big data electric energy metering module opportunistic topology would be connected with the external interface of the opportunistic electromagnetic coupling system.

The assimilation of opportunistic topology module mainly considers the electric energy region and the combination coil structure. Basis of assimilation is the characteristics of electromagnetic alternating coupling and mutual inductance. The electric energy transfer of the electromagnetic coupling system has the reage of nonlinear space. The nonlinear interval may increase the reverse probability of magnetic coupling mechanism. When the electric energy of opportunistic electromagnetic coupling system is measured and analyzed, it is necessary to solve the problem of electromagnetic field opportunity alternating. In order to solve the above problems, to improve the reliability of opportunisstic electromagnetic coupling system, the following conditions have to be satisfied: initialization of electric energy metering current coil coupling, optimization of mutual inductance, optimization of self-inductance, the adjustement of the coil number and the local optimization of control parameters. The judgment of these conditions can be given by formula (1), (2), (3), and (4) respectively.

The current I_0 of the electric energy metering coil can be initialized according to the instantaneous voltage, the cross-sectional area and the mutual inductance of the coil, and the upper limit value can be calculated according to the formula (1).

$$I_0 = \left\lceil O_I \mu_0 \frac{UN_1N_2S}{\sqrt[2]{a^2+r^2}} M_{(1,2)} \left(\sum_{i=1}^{N_1} M_{1i} + \sum_{j=1}^{N_2} M_{2j} \right) \right\rceil \tag{1}$$

Here, U represents the instantaneous voltage, N_1 and N_2 represent the number of the coil turns. S represents the mean coil area. Parameter a indicates coil size parameters. Parameter r represents the coupling distance of the measurement object. $M_{1,2}$ indicates the mutual inductance between the combined coils. M_{1i} represents the internal mutual inductance of the coil 1, which indicates the internal mutual inductance of the coil 2. O_I represents opportunity control factor. Parameter μ_0 is the magnetic conduction rate.

Optimization of mutual inductance M_{MI} and self inductance M_{SI} have to satisfy the conditions shown in formula (2).

$$M_{MI} \le M_{SI} \mu_r \frac{N_1N_2S}{\sqrt{\left|a^2-r^2\right|}} \tag{2}$$

Here, μ_r is the magnetic conduction rate of measuring distance *r*.

Parameter L_1 indicates the number of the coil 1 turns. Parameter L_2 indicates the number of the coil 2 turns. The maximum number of the coil turns must satisfy the following conditions.

$$\left(L_1, L_2\right)_{\max} \le I_0 \mu_r \frac{U}{\sqrt{\left|a^2-r^2\right|}} \tag{3}$$

The mean O_{MV} and variance O_{VA} of the local optimization of the opportunistic control parameters must satisfy the following conditions.

$$\begin{cases} O_{MV} \ge \dfrac{\mu_0}{1+\left|\sum_{i=1}^{N_1} M_{1i} - \sum_{j=1}^{N_2} M_{2j}\right|} \\ O_{VA} \ge \dfrac{\int M_{12} \cos\alpha dt}{S} \end{cases} \tag{4}$$

Here, α is the angle between the magnetic field and coil.

III. Electric Energy Measurement for Network Scheduling Ofbig Data Resonant Cavities

On the basis of the electromagnetic coupling system, the effect of the power transmission network on the electric energy measurement can be further eliminated by constructing a resonant cavity based on big data. Big data of the resonant cavity can be used in the near field of power terminal state solutions. The state of big data resonant cavity is described as: resonant angle frequency, big data driving factor and opportunistic state weight. The resonant angular frequency is obtained by the combination of the coil size and the turn number of the electromagnetic coupling system. Big data driven factors reflect the scale of the measurement data of electric energy metering objects. The factor is determined by the quality factor and the coupling level of the electromagnetic coupling system. The opportunistic state weights are used to react the opportunistic electric energy terminal state in near field. The big data resonant cavity integral line can be obtained through the parallel connection between the printed conductive body and the capacitor. The external antenna and the electromagnetic coupling system are mutual coupling. The printed conductive body adopts the cross structure of the fixed size. The printed area and the number of teeth cross determine the opportunistic coupling degree and the quality factor of the big data resonant cavity. The external port is designed on both sides of the resonant cavity, so that the radio can be measured from one end to the other end. It can reduce the energy loss of the resonant cavity and enhance the transmission spectrum of the cavity. Big data resonant cavity structure is shown in Fig. 2. The equivalent circuit of the resonator is shown in Fig. 3.

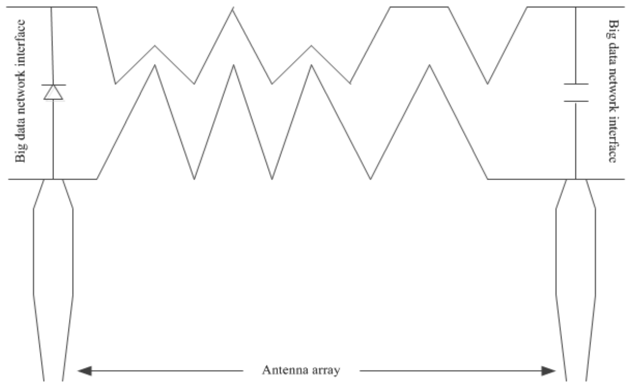

Fig. 2. Big data resonant cavity structure.

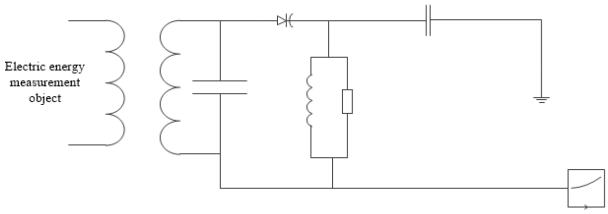

Fig. 3. Equivalent circuit

The total impedance Z of the electromagnetic coupling and the big data resonant cavity is shown in the formula (5).

$$Z = \frac{R_L + R_S}{1 + 2\pi j\omega\cos\alpha} \tag{5}$$

Here, R_L is the load resistance. R_S internal cavity. ω is the resonant angular frequency.

In order to obtain the circuit quality factor of the big data resonant cavity, the capacitance of the variable capacitance and the diode in parallel are coupled into the electromagnetic coupling system. This can make the whole system to be in a resonant state. Assuming that the input module and the output module do not exist coupling probability. The resonant state of the electric energy metering system resistance R_{re} and capacitance C_{re} are given in the formula (6).

$$\begin{cases} R_{re} = \dfrac{R_S\sqrt{\omega_0^{\ 2} + \alpha_0^2}}{R_L\omega^2} \\ C_{re} = \dfrac{C_L}{1 + \sqrt{\omega_0^{\ 2} + \alpha_0^2}} \end{cases} \tag{6}$$

Here, ω_0 is the angular frequency of big data resonant cavity. α_0 is the included angle between the center line of the coil and the normal line of the resonant state. C_L is the load capacitance value.

In order to ensure the integrity of the resonant cavity of the electric energy metering, the adaptive scheduling of the external network is fully realized. After the scheduling and mapping of the multi-port network transfer and matrix optimization, the coupling capacitance, transmission line and antenna array are fused into a two ports network. The transmission matrix of the transmission line of the big data network scheduling is shown as formula (7).

$$\begin{pmatrix} N_1 & N_2 \\ N_3 & N_4 \end{pmatrix}_{DP} = \begin{pmatrix} 2\pi\cos\alpha & \dfrac{R_{re}}{R_L + R_S} \\ \dfrac{1}{\sqrt{\alpha^2 + \omega^2}} & \dfrac{C_{re}}{C_L + \cos\alpha_0} \end{pmatrix} \tag{7}$$

The coupling capacitive transmission line matrix of the big data resonant cavity opportunity control circuit in the opportunistic coupling system is given by the formula (8).

$$\begin{pmatrix} N_1 & N_2 \\ N_3 & N_4 \end{pmatrix}_{C} = \begin{pmatrix} \dfrac{\omega_0}{2\pi} & \dfrac{R_{re}}{2\pi\omega} \\ \dfrac{1}{\sqrt{\alpha^2 + \omega^2}} & \dfrac{1}{C_L + \cos\alpha} \end{pmatrix} \tag{8}$$

Big data resonant cavity of the network scheduling of electric energy metering operation flow is shown in Fig. 4. Electric energy measurement result is given by

$$u(t) = \frac{I_0\sin(2\pi\alpha_0) + jU\cos\alpha}{R_{re} + jZ} \tag{9}$$

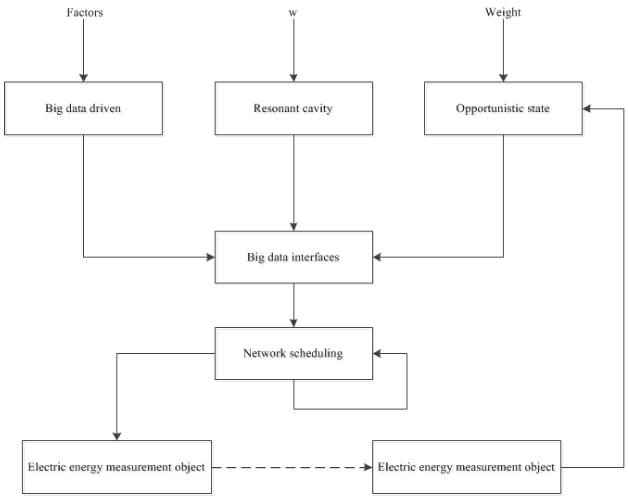

Fig. 4. Electric energy metering operation flow of network scheduling.

IV. Performance Analysis of Electric Energy Measurement in Big Data Network

The electric energy metering algorithm with opportunistic electromagnetic coupling and resonant cavity big data network scheduling has been realized in the hardware platform. In order to close to the measurement of the actual power grid, we add the frequency offset as shown in Fig. 5. The frequency offset is simulated by inverse Fourier transform and power signal sampling curve. Fig. 5 shows the multiple frequency peaks and troughs. The frequency of these mutations weakens the hysteresis of the inverse Fourier transform. Frequency offset can detect the power tracking efficiency and measurement accuracy of the power measurement algorithm.

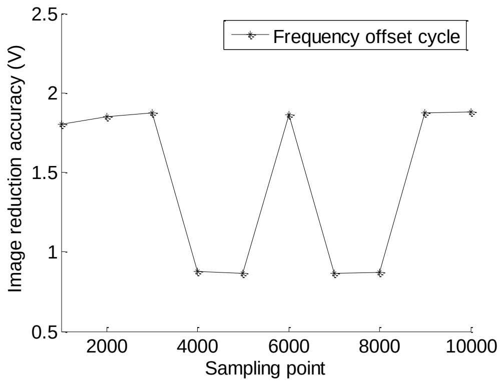

Fig. 5. Embedded system extensibility

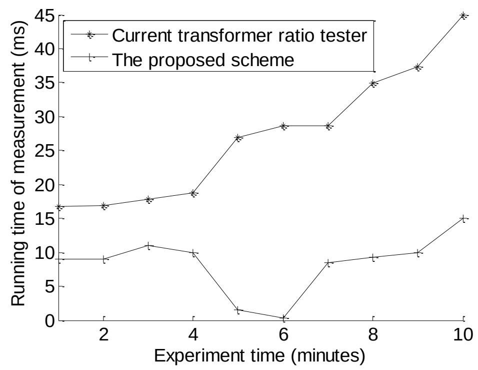

Fig. 6. Running time

The unit step input signal disturbance and interference source signal are generated in the laboratory. These disturbing signals are added to the electric energy measurement objects, which are used to evaluate the operation time and measurement precision of electric energy metering algorithm. Test data period is 20 Millisecond. The sampling rate of electrical signal is 62.5 kHz.

Fig. 6 shows the running time results of current transformer ratio tester and the proposed algorithm. From Fig. 6, running time of current transformer ratio tester is very close with the proposed algorithm in 2 minutes. This is because the opportunistic electromagnetic coupling system and resonant cavity are in the initial stage. After 2 minutes, hardware lag performance of current transformer ratio tester is very obvious. The tester is always in an active state. However, the running time of the proposed algorithm is shortened. Then, the algorithm is in a sleep state at 8 minute. The above results show that the proposed algorithm can be completed with the same workload of current transformer ratio tester in a short period of time. The proposed algorithm ensures the real-time and high efficiency of electric energy measurement by the opportunistic control of the electromagnetic coupling system and the cavity structure.

Fig. 7 shows the measurement accuracy of current transformer ratio tester and the proposed algorithm. A big data resonant cavity and network scheduling algorithm are established in the proposed algorithm. The proposed algorithm can solve the recognition problem of measurement object and improve the measurement accuracy in big data network. These problems are difficult to be solved in the hardware equipment. In addition, in the Fig. 8, the proposed algorithm can activate more measurement objects in a short time. The current transformer ratio tester cannot achieve the same effect.

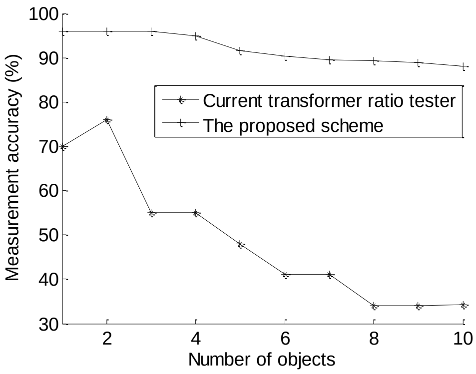

Fig. 7. Measurement accuracy

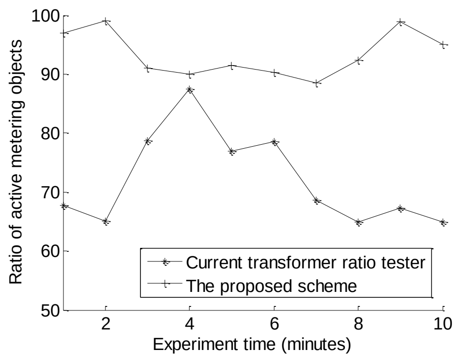

Fig. 8. Ratio of active measurement objects

V. Conclusions

There are the problem of low measurement accuracy and high cost of measurement in traditional electric energy metering scheme and metering equipment in the large-scale electric energy measurement. In view of the above problems, this paper proposes a new power measurement mechanism based on the opportunistic electromagnetic coupling system and big data resonant cavity network scheduling. On one hand, in order to improve the working efficiency and energy efficiency of the electromagnetic coupling system, a new method of electric energy measurement is proposed. The system includes opportunistic coupling mechanism, electromagnetic opportunity structure and opportunity control parameter. On the other hand, in order to eliminate the influence of power transmission network on electric energy measurement, a kind of near field opportunistic electric energy terminal state scheme is proposed. The scheme contains a big data resonant cavity. On the basis of the above schemes, the operation flow of the network scheduling in big data resonant cavity is given. Experimental results show that the proposed algorithm has advantages in real-time, accuracy and efficiency of the electric energy metering.

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