Research on Renewable Energy Access to Power Grid Based on Energy Internet Technology

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Abstract. The Internet of Energy is the key to achieving the goals of China's energy revolution, and Internet technology will become an important means to promote the transformation and development of China's energy industry. Based on the analysis of the current research status of virtual synchronous machines, an implementation method of a virtual synchronous machine algorithm based on a synchronous rotating coordinate system is proposed. This algorithm does not require a phase-locked loop, which greatly improves the accessibility of renewable energy and realizes its transformation from auxiliary energy to main energy. Simulation results verify the effectiveness of the proposed algorithm.

1. Introduction

Energy Internet takes the power system control network as the core, integrates many distributed renewable energy sources, and uses information communication and other technologies to realize the two-way flow of energy and information. Power line communication mainly includes power line carrier and power line power frequency communication technologies, and they do not need to set up special lines. No public communication service fees, can effectively use the grid company's own resources, under the energy Internet architecture, in the field of distributed energy access, microgrid optimization operation, active load monitoring and other fields have broad application space.

Renewable energy mostly uses grid-connected devices based on power electronic converters. Compared with traditional generators which use grid-connected synchronous generators, power electronic devices have the characteristics of small inertia, no damping effect and fast response speed. In the context of large-scale development of renewable energy, in order to improve the ability of the grid to accept it, a new mechanism for grid connection of renewable energy generation needs to be explored [1].

2. Energy Internet and Distributed Energy

2.1. Energy Internet

Energy Internet is a shared network that is tightly coupled with power system control networks, intelligent transportation networks, natural gas networks, and other network systems. The composition of the Energy Internet is shown in Figure 1. The key technologies of Energy Internet include the
following parts: information and communication technology, management and scheduling technology, security and protection technology, energy system technology, and system planning technology system.

Figure 1. Composition of Energy Internet

Figure 2. Energy Internet Technology Architecture

Optimizing energy use structure, improving energy use efficiency, and improving user experience are the development goals of Energy Internet. Only by determining the specific constituent elements of the Energy Internet can we define the scope of optimization of the Energy Internet. In order to achieve the development goals of the Energy Internet, we must first identify the constituent elements of the Energy Internet. Based on defining the optimization scope of the Energy Internet, in order to improve the efficiency of energy use from a technical perspective, it is necessary to study the technical
components of the Energy Internet and the technical architecture diagram of the Energy Internet. As shown in picture 2 [2]. The energy Internet technology architecture mainly includes energy supply, energy transmission, energy conversion, information sharing, and scheduling control. Among them, energy supply, energy conversion and energy consumption are the energy flows in the Energy Internet. Information sharing is the information flow of the Energy Internet. Energy flow and information flow are also the ultimate optimization objects of the entire technical framework. Scheduling control is the core of the overall energy optimization content.

2.2. Distributed Energy
"Distributed energy" refers to a comprehensive energy utilization system distributed on the user side. It is based on the input of many energy resources, the output of main energy products with cold, heat and electricity, and the regional energy production, supply and distribution based on distributed energy systems, distributed networks and distributed (intelligent) control technologies., Sale and use integrated system. In order to improve the way electricity is used, relevant activities carried out by scientific electricity consumption, energy conservation and orderly electricity consumption are carried out, as shown in Figure 3 [3]:

![Schematic diagram of distributed energy system](image_url)

**Figure 3.** Schematic diagram of distributed energy system
Power demand side management (DSM) refers to the load management and technical transformation of end users in order to improve the efficiency of power resource utilization, to average the use of electrical loads, to improve the efficiency of terminal energy use, and to implement comprehensive resource planning. There are three ways for distributed energy systems to participate in demand-side management: Store excess electrical energy generated by distributed generation in energy storage equipment during periods of low power consumption, and release them to the large power grid during peak periods of power consumption to achieve “peak-cutting” “Filling the valley” guarantees the dynamic and stable load of the power grid; assists in power supply or transmission of electrical energy in the event of a power grid failure or natural disaster; and guarantees the user's power demand in the event of a forced power outage or power outage.

3. Renewable energy grid-connected optimization scheduling
The UC problem can be described as: within a certain scheduling period (usually 24h, under the constraints of system power balance, standby requirements, and unit operation), determine the starting and stopping mode of the unit and the output plan of the operating unit in each period, so that The total operating cost during the scheduling period is optimized. The decision variables of the UC problem are the start-stop status and active output of each generator set [4].

3.1. Objective function
At present, the objective functions of UC problems are mostly extended from the objective functions of traditional economic dispatch problems. The objective function of traditional economic dispatch is to minimize the cost of power generation. The cost of power generation mainly includes the coal consumption cost and start-up cost of the generating set. The objective function is expressed as follows:

$$\min F = \sum_{i=1}^{N_T} \sum_{j=1}^{N_G} \left[ f_i(P_{G,i,t}) + C_{Gsc,i} \left(1 - u_{i,t-1}\right) u_{i,t} \right]$$

In the formula: $N_T$ is the total period of the study, $N_G$ is the number of conventional generating units; $P_{G,i,t}$ is the active output of unit $i$ in period $t$; $u_{i,t}$ is the operating state of unit $i$ during period $t$; $C_{Gsc,i}$ is the start-up cost of the unit, which can be expressed as $C_{Gsc,i} = K_i + B_i (1 - e^{-Z_{i,t-1}/\tau_i}) K_i$, $B_i$, $\tau_i$, and are the start-up coefficients of the unit i, and $Z_{i,t-1}$ is the continuous shutdown time of the unit Ki before the Kt period. $f_i(P_{G,i,t})$ is the coal consumption cost of the unit i during the t period, which is usually expressed as a quadratic function of active power output, that is, $f_i(P_{G,i,t}) = a_i P_{G,i,t}^2 + b_i P_{G,i,t} + c_i$ Where $a_i$, $b_i$, $c_i$, are the corresponding cost coefficients.

3.2. Constraints
Constraints mainly include system operation constraints and generator set operation constraints. The system operation constraints mainly include power balance constraints, rotation reserve constraints, and line transmission power constraints. Generator set operation constraints mainly include technical output constraints, climbing rate constraints, and minimum start-stop time constraints [5].

$$\sum_{i=1}^{N_G} u_{i,t} P_{G,i,t} = P_{L,t}$$
\[
\sum_{i=1}^{N_G} R_{G,i,t} \geq R_t
\]  

(3)

\[
R_{G,i,t} = \min(u_{i,t} P_{G,i}^{\text{max}} - P_{G,i,t}, P_{G,i,t}^{\text{max}})
\]  

(4)

\[-P_i^{\text{max}} \leq \sum_{i=1}^{N_G} K_{i,t} P_{G,i,t} - \sum_{n=1}^{N_D} K_{n,t} P_{n,t} \leq P_i^{\text{max}}
\]  

(5)

Equation (1) is the system power balance constraint; Equations (2)-(3) are system rotation reserve constraints; Equation (4) is the line transmission capacity constraint. \(N_D\) is the number of loads; \(P_{L,t}\), \(R_t\) is the system load and reserve demand of the time period \(t\); \(P_{G,i}^{\text{min}}, P_{G,i}^{\text{max}}\) is the lower and upper output limit of the unit \(i\); \(R_{G,i,t}\) is the rotating reserve capacity provided by the unit \(t\) of the unit \(i\); \(R_{G,i,t}^{\text{max}}\) is the maximum capacity that the unit can provide Spm reserve capacity.

4. Simulation analysis

This paper builds a renewable energy grid-connected inverter system based on the virtual synchronous machine algorithm in the MATLAB / Simulink environment. The main parameters are as follows: filter inductance \(L\) is 0.5 mH; filter capacitor \(C\) is 47 μF; damping resistance \(R_d\) is 1 Ω; The DC bus voltage \(U_{dc}\) is 800 V; the switching frequency is 10 kHz; the effective value of the grid phase voltage is 220 V; the grid frequency is 50 Hz; the damping coefficient \(D\) is 10; the inertia constant \(J\) is 45; the proportional coefficient \(K\) is 0.001. The converter operates with a power command of 10 kW / -5 kvar at the initial moment, and the active power command switches to 8 kW at 3.5 s, and the reactive power command does not change. The output power of the virtual synchronous generator is shown in Figure 4. From the simulation waveforms in Figure 4, it can be seen that the power response of the virtual synchronous machine has a certain overshoot when it starts, and its response speed is slow when the power command changes, and the frequency is maintained near the set value of 314.15 r / s, which reflects the inertia and damping of the synchronous machine. Effect. During the start-up phase of the virtual synchronous machine, a small amount of distortion occurs in the grid-connected current waveform, and a steady state value can be reached within 3 cycles, and the waveform sine degree is good. At 3.5 s, the power command changes, and the grid-connected current changes slowly. It reaches a steady state value within 2 cycles without overshoot [6].
5. Conclusion
Aiming at the problems of large-scale renewable energy access and grid connection in the energy Internet, the stability margin and inertia of the system are reduced. This paper proposes a virtual synchronous machine algorithm implementation method based on a synchronous rotating coordinate system. The algorithm does not require a phase-locked loop (PLL), can provide inertia and damping support to the power grid, and can participate in the frequency response of the power system, thereby greatly improving the access to renewable energy. Simulation results verify the effectiveness of the proposed algorithm.

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