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China's electricity transmission and distribution tariff mechanism based on sustainable development

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ABSTRACT

In order to guarantee the rapid sustainable development of the social economy, the power grid will make large investments in the construction of smart grids, the renewable energy network, the construction of long-distance transmission grid channels as well as the technology and service innovation of the power grid. According to the electricity transmission and distribution tariff accounting mechanism of costs and benefits, the power grid investment needs to be recycled by the transmission and distribution tariff. However, at present, the low electricity transmission and distribution tariff in China, which is based on the difference between the electricity sales price and the average purchase price, cannot guarantee the return of investment and the sustainable development of the power grid. Based on the current situation of China's power grid construction and electricity transmission and distribution tariff, this paper proposes that the new investments in the power grid can be divided into technical innovation investments, environmentally friendly investments, service promotion investments and other kinds of investments, according to their functions. Then, four electricity transmission and distribution tariff and power grid investment linkage models are built and example analysis undertaken, respectively, which are the timely linkage model, static linkage model, ladder linkage model, in which the electricity tariff space changes by a fixed absolute value annually and ladder linkage model in which the electricity tariff space changes by a fixed proportion value annually. The results reveal that the ladder linkage model in which the electricity tariff space changes by a fixed absolute value annually can guarantee relatively smooth changes in the electricity tariff, and is suitable for the actual situation of China's power market. The transmission and distribution electricity tariff and power grid investment linkage models based on sustainable development built in this paper are beneficial for promoting the reforms of the electricity transmission and distribution tariff in China and guiding the establishment of a scientific electricity tariff mechanism.

Introduction

In recent years, the rapid development of China's power industry has provided strong support for economic and social development. At the same time, low-carbon environmental problems have become social issues that need to be resolved. Hydropower, wind power, solar power and other renewable energies can be developed on a large scale in China. However, they are far from the load centre and need large-scale and long-distance transmission. Therefore, it is necessary to accelerate the development of the smart grid in order to enhance the energy security, improve the comprehensive utilization efficiency of energy and ensure the sustainable development of energy [1]. In May 2009, China formally proposed the construction of smart grid concepts and goals, and divided the construction of the smart grid project into three stages: the planning stage, building stage and upgrading stage. It is estimated that China will invest over 3 trillion yuan in building a national grid from 2013 to 2020. Through the power grid construction in the future, the national grid will plan to ensure the delivery and consumption of 550 million kW of clean energy. The annual consumption of clean energy will be 1.7 trillion kW, which can be an alternative to 510 million tons of standard coal, and the reduction in carbon dioxide emissions will be 1.42 billion tons while the reduction in sulphur dioxide emissions will amount to 1.5 million tons.

At present, China's electricity transmission and distribution tariff can be divided into three levels according to the grid structure

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and management system: (1) the inter-regional power grid, including transmission interconnection projects and special transmission projects; (2) the inter-provincial power grid, which has no uniform pricing mechanism and mainly implements negotiation pricing and cost sharing based on pricing principles decided by the Government; (3) the provincial power grid, for which the electricity transmission and distribution tariff reflects the difference in the average purchase price and sales price. China has not yet formed a complete system for the electricity transmission and distribution tariff, and the transmission and distribution tariff of the provincial power grid faces a squeezing dilemma in that it is difficult to meet the needs of the rapid development of the power grid. Meanwhile, the electricity price structure in China is irrational and the level of the electricity transmission and distribution tariff is low. In 2011, the average electricity transmission and distribution tariff (excluding line losses) was 186.67 yuan/MW h, which accounted for 32.01% of the electricity sales price. Furthermore, the cross-subsidies of the Chinese electricity sales price are mainly reflected in the transmission and distribution tariff. Once the Government has implemented a preferential tariff, it is often assumed by the electricity transmission and distribution tariff, and it will impact on the operation of the power grid.

The power grid has natural monopoly characteristics and cannot introduce free competition. In order to allocate resources rationally, reflect market relations effectively, ensure the conduct of social production and maintain the interests of consumers, many countries have established an effective regulatory framework for the efficient operation of the power grid. Currently, the common transmission and distribution price control models are mainly price cap regulation, revenue cap regulation, rate of return regulation, the franchise competition system, the inter-regional comparative competitive system, etc. [2,3]. The British Government imposed the price cap regulation method, which was proposed by Professor Stephen Littlechild [4], in the past. This control method uses the RPI-X model [5], in which PRI represents the retail price index and X represents the productivity growth percentage in a period determined by the regulator. In the coming years, as decarbonisation and market integration efforts are intensified, it is projected that a very significant amount of transmission investment will be needed for the British power grid [6]. In order to encourage enterprises to improve their efficiency further and adopt innovative technology, the regulatory agencies decided to use the RIIO model to control the transmission tariff from April 2013. The U.S. imposes the rate of return regulation method for the grid transmission tariff and has a long history. This control method is beneficial to encouraging investments in power grid enterprises, but not conducive to improving the efficiency of government regulation. Meanwhile, this method stimulates enterprises to increase their capital investment to gain more profits, and it is easy to create the A–J effect [7]. Finland also adopted the rate of return regulation for power grid enterprises, and the regulation framework sets an allowed rate of return on the asset base, which is the current replacement cost of the network. The replacement cost is set by the regulator's valuation of the network components [8]. The electricity tariff in Thailand is based on the two main costs of electricity production, the based operational cost and fuel adjustment, of which the based operational cost is classified as the rate of return regulation that sets the electricity tariff based on the revenue requirement for Thai state-owned enterprises' electricity utilities to ensure the stability of their financial position and the ability to expand the operations of the power utilities [9]. Matsukawa [10] investigated the long-run effects of average revenue regulation on an electricity transmission monopolist, and found that a binding constraint on the monopolist's expected average revenue lowered the access fee, promoted transmission investment and improved consumer surplus. Ruiz and Rosellón [11] presented a mechanism to promote electricity transmission network expansion in the Peruvian electricity transmission system, which combined the merchant and regulatory approaches to promoting investment in transmission grids.

In an electric power market, proper transmission pricing could meet revenue expectations, promote an efficient operation, encourage investment, and adequately reimburse owners of transmission assets [12]. In European, under current trends in the evolution of transmission tariffs, only half the volumes of investment currently planned could be funded, so a highly significant increase in transmission tariffs will be required [13]. Meanwhile, the transmission pricing method should be simple, feasible and beneficial to a fair and open electricity market, and should allow easy oversight and inspection of the supervision department as well [14–16]. The transmission tariff can be formulated using several methods, and the cost method of accounting and the marginal costing method are mostly adopted [17]. First, determine the annual revenue requirement or the annual maximum allowable income of the transmission grid; then, share the revenue using various sharing methods; finally, obtain the transmission tariff according to the sharing annual revenue requirements and users' electricity consumption. The specific methods include the postage stamp method, transaction path method, line-by-line calculation method and MW mile method. Beckman [18] described the evolution of cost allocation for India's inter-state transmission system and examined the impacts of the shift from a regional postage stamp method to a flow-based cost allocation charging method. Kristiansen [19] made a comparison of three transmission pricing models: the Wangensteen model, the optimal power flow model and the Hogan model. The similarities among the models are that they can all be used in locational pricing systems. Chen et al. [20] proposed a novel transmission pricing scheme for the pool power market based on pay-as-bid (PAB). It provided economic signals to promote the maximum use of the existing transmission network, encouraged appropriate bidding behaviours in the pool and helped to reduce the possibility of the enforcement of market power and the appearance of price spikes, thus improving the market operation efficiency and trading effects. Telles et al. [21] put forward a new transmission tariff computation (TTC) approach based on the long-run marginal costs (LRMC) method and the min.–max. optimization technique, which can be employed to optimize tariffs for generators and loads jointly or separately. Radzi et al. [22] introduced a novel transmission pricing method which was called Distribution Factors Enhanced Transmission Pricing (DFETP) method in order to increase the utilization efficiency of the network as well as to promote the green technology in a market environment. Bharatwaj et al. [23] presented a new transmission pricing paradigm based on the flexible mix and match approach, which aimed to create a generic flexible toolbox that considers the viewpoints and preferences of all the stakeholders. Nikoukar and Haghifam [24] proposed a simple transmission pricing scheme using the tracing method based on the proportional tree, in which the transmission fixed cost, congestion cost and loss cost are considered. It can provide useful economic information to market users, such as generation companies, transmission companies and customers.

The above references focus on transmission and distribution tariff regulation methods and pricing methods, and they have certain significance for China. However, nowadays there are huge investments in China's power grid, and they cannot be recycled in the form of the electricity transmission and distribution tariff. This brings some difficulties to the sustainable development of power grid enterprises, so it is necessary to establish linkage adjustment mechanisms for the electricity transmission and distribution tariff and power grid investments. Based on the current contradiction of Chinese electricity transmission and distribution