This article is published online with Open Access by IOS Press and distributed (ICC BY-NC 4.0).

of the Creative Commons Attribution Non-Commercial License 4.0 (CC BY-NC 4.0).

doi:10.3233/FAIA231199

Ordered Tree Billing Algorithm and Its Application in Power Marketing System

Ke ZHU, Juan KONG¹, Gen-Xin XIONG, Wen-Juan SHI, Yun LI, Hong OUYANG and Yu-Xi LIU

Beijing China-Power Information Technology Co., LTD., Beijing, China

Abstract. The electricity is essentially a function of electricity customers and their electricity consumption. The electricity contract generally stipulates the calculation method of electricity price rather than one or a set of clear and fixed prices. The electricity price is subject to provincial policies, user classification, electricity price type, The impact of new energy, etc., will generate electricity charges, refunds and other services. In addition, in the absence of unified national supervision, it is difficult to update the electricity billing system in each province, and at the same time, the calculation of electricity bills is extremely complicated. This paper proposes a general billing algorithm based on ordered tree, which can construct a variety of complex rules through flexible assembly of basic rules, which can meet the billing needs of utility companies. The power charge engine implemented based on this algorithm can adapt to the different electricity bill calculation rules in different provinces, changing the unfavorable situation that the original marketing system lacks a unified billing module, and it is difficult to quickly respond to government and market requirements, as well as the headquarters' management and supervision requirements for provincial and municipal companies, and the operating efficiency is higher than the original hard-coded billing module. Finally, the power charge engine also effectively improves the versatility, reliability and operational efficiency of the existing State Grid marketing system.

Keywords. Ordered tree, billing algorithm, utilities, power charge engine, marketing system

1. Introduction

Billing is the central and core business of power marketing [1,2,3], and an important work content of utilities such as electricity, water, gas and heat [4,5]. It mainly includes the payment and settlement of electricity, water, gas, heat, operational expenditure and value-added service fees between utilities and their customers. For power companies at all levels, it is important for enterprises to adapt to the requirements of power market reform and the new trend of the energy market [6, 7] by innovating the traditional electricity fees management mode, strengthening the construction of internal control mechanism, and strengthening capital risk prevention. Therefore, it is necessary to carry out the accounting, collection, payment, accounting research and implementation of algorithms and support systems for a series of ticketing services [8,9].

¹ Corresponding author: JUAN KONG, Beijing China-Power Information Technology Co.,LTD., Beijing, China, E-mail: 15032358287@163.com.

Scholars at home and abroad have done some research on the electric charge charging algorithm. Literature [10] designed an intelligent system architecture for marketing accounting based on the new business model of integrating meter reading plan, data preparation, automatic meter reading and indicator verification. In document [11], in order to solve the problem of low reliability and responsiveness of existing marketing systems, programmable logic devices were selected in hardware and automatic meter reading mode was designed in software. The literature [12], supported by the data of the measurement automation system and the marketing management system, provides customers with the optimal basic electricity charge calculation method based on data analysis. Literature [13] studies and gives a two-part pricing model based on the background of formulating a two-part electricity price menu with eight options including two-part electricity price, capacity electricity price, electricity electricity price, etc. for industrial users with 315 kVA capacity and above. The literature [14] designed two core processes of the electric power marketing management information system, namely, the electric charge reading, verification and collection and the customer industry expansion, in combination with the design idea of the electric power marketing management information system of Kaiping Power Supply Bureau. The above documents optimize the billing algorithm on the original power marketing system to achieve mutual benefit between power enterprises and users. However, it ignores the difference of electricity billing services in different provinces and the integration of marketing system algorithm modules. The optimization of any module of the algorithm will have an impact on the entire marketing system. Document [15] introduces the billing engine of SAP, which can realize flexible configuration of billing algorithm. However, it is ignored that before the reform of the power sales side of the power system, the electricity price system of each province was basically the same. The power marketing system directly translated the billing business rules into software codes for electricity charge calculation, which did not affect the universality of the marketing system. With the continuous deepening of the reform of the power sales side of the power system, the provincial and municipal development and reform commissions have continuously adjusted the electricity tariff rules, and the billing modules of the provincial marketing systems also need to follow the adjustment, which makes the marketing system lose its universality and unity. In addition, the marketing business system is complex and huge, and it takes a lot of manpower and material resources to modify the code, which makes it difficult for the marketing business to respond to policy changes in a timely manner.

Therefore, this paper takes the IS-U utility system of SAP Company, which has a good universality of electricity charge calculation, as a reference, and puts forward a general billing algorithm based on an ordered tree. This algorithm can adapt to the changing electricity charge rules of each province through the way of independent configuration by business personnel, which solves the shortcomings of frequently modifying the marketing system code in the past. Finally, through the example and performance analysis, the algorithm effectively improves the universality, reliability and operating efficiency of the marketing system.

2. Pricing System Based on Policy Differences - Construction of Billing Process

2.1. Differentiated Electricity Price System for Multiple Market Entities

Electricity price is the selling price of electric energy commodity and the monetary expression of electric energy value. The electricity price is composed of the cost, tax and profit of electric energy. The Electricity Regulatory Commission and the Energy Bureau put forward adjustment opinions on the electricity price policy and the electricity price level. The adjustment of residential electricity price shall be formulated by the NDRC in the price adjustment hearing. The electricity price is based on the cost, and the use of price is the market lever. Different electricity prices are formulated according to different types of users, so as to promote users to improve their electricity conditions, improve their equipment utilization and load rate, and improve the power supply capacity of the grid as much as possible.

The electricity price system determines the electricity price and billing method of users according to customer classification, electricity consumption category, pricing strategy and other conditions. According to the classification of users, the electricity price system can be divided into power users and power generators. Power users are divided into high-voltage, low-voltage and market-oriented users. The electricity price varies with the nature of users. The electricity price of electricity users mainly includes the catalog price, the additional price, the basic price, the power adjustment price, etc; The electricity price of power generation households mainly includes the on grid electricity price and subsidy electricity price. The research content of this paper is based on the telephone electricity price system.

2.2. Design of Billing Process Based on Policy Orientation

Electricity charge is composed of electricity price and electricity quantity. Due to the complexity of electricity price system and the diversity of electricity metering methods, the functional relationship between electricity quantity and electricity price is more complex. The electricity price system has dynamic characteristics, which is affected by policies, power generation energy supply, new energy distribution, market demand and other factors. Due to different economic systems in different provinces, the corresponding electricity price system is also different. For 490 million electricity consumers, the calculation of electricity charges is complex and the amount of data is huge. In combination with the relevant policies proposed by the National Development and Reform Commission, the billing process is designed as seven steps: formulating the metering plan, data preparation, meter reading data entry, meter reading data review, electricity charge calculation, electricity charge review, and electricity charge issuance.

The formulation of volume fee plan is the work of using computers or mobile terminals to generate a volume fee distribution plan based on designated users or a collection of designated users. Data preparation refers to the work of re organizing and storing the necessary data information of customer files, billing parameters, power supply, electric energy meters and other billing information involved in the billing plan into the billing snapshot after being extracted according to the billing rules by using computers according to the business requirements of the billing distribution plan according to the policies, regulations and contracts. Meter reading data entry refers to judging whether it is necessary to manually enter meter data according to the type of onsite meter after data preparation. If it is a smart meter, the meter data will be automatically

obtained. Recheck of meter reading data refers to rechecking the obtained meter readings and recording the abnormal readings. The calculation of electricity charge is based on the plan, user file information, meter reading information and algorithm model developed this time. The review of electric quantity and charge is based on the application number, plan number, and business type, and uses the review rules to review the calculation results of this quantity and charge, and records the work of abnormal quantity and charge review. Volume fee issue is to complete volume fee issue and generate A/R and A/P based on the user file, issue plan, and the results of volume fee accounting without exceptions.

3. Billing Design Based on SAP Public Utilities

SAP Utility Industry Marketing Solutions provide SAP Customer Care and Services (SAP IS-U/CCS). SAP IS-U/CCS covers power marketing businesses such as metering management, meter reading management, billing management, accounting management, and work order management [16,17,18]. SAP IS-U/CCS billing management can flexibly define the billing scheme required by the configuration of power supply enterprises, and it is simple in structure and easy for users to operate. When calculating the user's electricity fees, the charging engine can be configured to generate a charging scheme suitable for each scenario, such as simple scenarios such as non time sharing normal reading calculation of residents, meter reading non resident electricity price changing to residential electricity price and other business scenarios; For complex scenarios, such as the single system of high supply and low calculation without time division (iron loss is not shared), the two-part system of high supply and low calculation without time division (iron loss is not shared), etc.

SAP IS-U/CCS billing management adopts a unified technical architecture. Billing management includes business requirements of each link of the billing process, contract account management, billing method calculation, etc. Contract account management establishes a one to many relationship with business partners. Business partners can represent groups, organizations, and individuals [19,20]. Contract accounts and contracts are one to many relationships, and a contract can only correspond to one contract account and one billing method. The contract can belong to different industries, such as water, electricity, gas and heat charges of a customer.

SAP billing method has the advantages of flexible assembly and configuration, but it can not meet the complex status quo of electricity consumption scenarios in China's electricity market, such as the demand for superposition of electricity charges, and the change of electricity price with the user's electricity consumption, electricity consumption nature, etc. Therefore, this paper proposes a billing model based on ordered tree, which is verified and popularized.

4. Billing Model and Electric Power Marketing Billing Engine Based on Ordered Tree

4.1. Billing Model Based on Ordered Tree

With the continuous deepening of the reform of the power sales side of the power system, the provincial development and reform commissions have continuously adjusted the

electricity tariff rules, and the billing modules of the provincial marketing systems also need to follow the adjustment, which requires that the marketing system be universal and unified, and can respond to policy changes in a timely manner. Therefore, this paper proposes a billing model based on ordered tree, and the implementation process is shown in Figure 1.

By combining the recursive principle of the ordered tree with the billing design of SAP, a billing model based on the ordered tree is proposed. The model is divided into four levels: process phase, basic component, activity component, and node component. One process phase contains multiple basic components, one basic component contains multiple activity components, and one activity component contains multiple node components. Each process phase, basic component, activity component, and node component are executed in order according to the configuration. Each process phase is extended inward to the smallest unit (node component) of the component, and then returns to the process phase layer by layer, and continues to execute downward.

Each step of the electric power billing process is regarded as a process link, which is divided into such process links as the formulation of metering plan, data preparation, meter reading data, etc. The basic component is to subdivide each process link according to the data function level, that is, to realize the underlying basic functions as standard components. For example, the process link of electricity charge can be subdivided into basic components such as reading electricity calculation, variable electricity loss calculation, line loss electricity calculation, etc. The active component is the secondary subdivision of the basic component, that is, the function that must be realized on the basis of the underlying business. The overall processing logic is different from that of the standard component. For example, the basic component of copy power calculation can be divided into active components such as installation point copy power calculation, return/supplement copy power calculation. If there is only some rule difference in the algorithm process, the node component should be established for differentiation processing. For example, the installation point reading electricity calculation component is divided into four parts: the total electricity is not equal to the electricity in each period and the leveling, and whether the reactive four quadrants participate in reading electricity calculation to determine whether to expand, the total electricity is not equal to the electricity in each period and the leveling component.

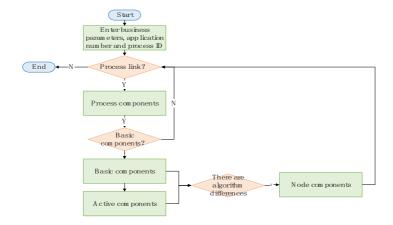


Figure 1. Billing Model Based on Ordered Tree

The applicable dimension of a component is a completely independent calculation process for the entire accounting plan (i.e., an accounting cell). After the calculation is completed, an independent calculation result is output, not the result of an intermediate process. A process phase consists of multiple basic components; A basic component consists of multiple active components; An activity component is composed of multiple node components, and finally forms a billing model based on an ordered tree. If some business rules of the active components between two provinces are inconsistent, different business rules can be added for the active components as node components to meet the billing requirements of different charging rules in different provinces (cities) across the country.

4.2. Design of Electric Power Billing Engine

The electric power billing engine can flexibly configure algorithm components based on the data prepared in the data preparation phase and SAP solutions, so as to achieve a set of systems that can adapt to the different billing rules of each province (city) and meet the billing business needs of each province (city).

The power billing engine is composed of process components, primary components, secondary components, extension points and extension implementations. The process component refers to the overall process of billing, which adopts the billing process of data preparation, meter reading, reading review, electricity charge calculation, and volume charge review. Process components are extended to Level 1 components. Level 1 components refer to the charging rules used in the calculation of electricity charges, such as reading electricity calculation, change loss calculation, line loss calculation, etc. The secondary components refer to the detailed division of the primary components. For example, the reading power calculation of the primary components includes the reading power calculation of the installation point and the reading power calculation of the return and supplement. An extension point is an extension of a secondary component. An extension point is set at the logical processing branch due to algorithm differences, and the extension point must have logical processing selectivity. Each extension point must have at least one extension implementation. When there are multiple extension implementations, the default extension implementation must be set. When there is no qualified extension implementation, the default extension implementation is executed. There are three types of extension implementations: parameter classes, static extension implementations (implemented encapsulated methods), and dynamic extension implementations.

5. Result Verification

Based on the ordered tree electric power marketing billing engine, the billing business rules can be flexibly configured to meet the differentiated billing business needs of each province (city). Taking the non market billing process in Jiangsu Province as an example, first define the component information used for billing, including process components, primary components, and secondary components, and configure the corresponding service class for each component. Secondly, the billing process is configured through the workflow definition, so that each process can be executed orderly. Jiangsu's non market billing engine is configured, as shown in Figure 2.

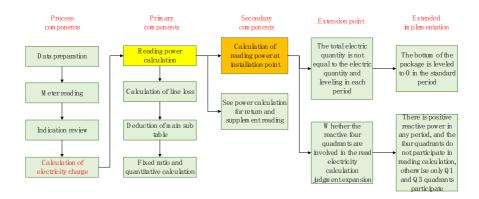


Figure 2. Configuration of Non-market Bbilling Eengine in Jiangsu

Configure the primary components of the billing model for the electric quantity and charge calculation process components, including the reading electric quantity calculation component, the transformer line loss calculation component, the constant ratio and quantitative calculation component, etc., and perform the electric quantity and charge calculation according to the configuration order. Configure secondary components on the basis of primary components. For example, secondary task components such as reading power calculation at the installation point and returning/supplementing reading power calculation are configured under the reading power calculation primary component. Due to the business difference between Jiangsu Province and other provinces, expansion points are configured under the secondary component of reading power calculation for the installation point, including whether the total power is not equal to the power in each period and leveling, and whether the reactive four quadrants participate in reading power calculation to judge expansion. Finally, due to the different business implementation methods between provinces, configure the expansion implementation corresponding to the expansion point. For example, configure the expansion implementation for the total electricity is not equal to the electricity in each period and the leveling expansion point, including the expansion implementation of the package bottom leveling in the standard period, until 0, and so on. Based on the ordered tree billing algorithm and the corresponding power billing engine configuration, the billing process, billing rules and implementation methods can be flexibly used, and the billing engine applicable to each provincial company can be configured, which effectively solves the problem of different billing business of each provincial company, and realizes the universality of the national grid marketing system.

At present, various provinces and cities across the country use multiple sets of power marketing systems. While ensuring the accuracy of billing results, they compare the billing time of Jiangsu, Zhejiang, and the billing engine based on the ordered tree. See Table 1 for the comparison of the calculation performance of the volume charge in May 2020. Compared with Jiangsu and Zhejiang billing algorithms, the billing engine based on the ordered tree can calculate the electricity charges of 910000 users in one minute, effectively improving the efficiency of electricity charge calculation.

Classification	Number of users	Total time(min)	Average time
Jiangsu	3900,0000	45	870000/min
Zhejiang	4000,0000	120	330000/min
Billing Engine Based on	1650,0000	18	910000/min
Ordered Tree			

Table 1. Performance comparison of volume and fee calculation in May 2020

6. Conclusion

The State Grid Corporation of China has 27 provincial and municipal companies under its jurisdiction. Influenced by the policies of each province and city, there are differences in billing rules. By integrating SAP's flexible and configurable model, a billing model based on an ordered tree and the corresponding power billing engine are built to achieve a set of state grid marketing systems that are applicable to the business needs of all provinces across the country, and can effectively monitor and manage the implementation of power consumption information and new electricity price policies in all provinces. Taking the billing business rules of Jiangsu Province as an example, by instantiating the billing engine proposed in this paper, and comparing the billing rates of Jiangsu and Zhejiang, it is confirmed that a set of electric power marketing system can meet the business needs of all provinces in the country, effectively improving the universality and billing rate of the existing electric power marketing system.

References

- [1] GE Zhouqing. Talking about the practice of the management of electricity marketing and electricity bill collection[J]. Economic Management Digest, 2020(17):49-50.
- [2] WEN Chaoyu, Guo Jiao. Analysis of Checking Collection and Intensive Accounting Management of Electricity Marketing [J]. Modern economic information, 2017(21):181.
- [3] LIANG Xilin.Research on Problems and Solutions in Power Marketing Copying, Checking and Receiving[J].China High-tech Enterprise, 2017(05):242-244.
- [4] LIN Bo, WANG Jing.Analysis on the centralized management of electric power marketing check collection and accounting[J].SME Management and Technology (late issue),2020(08):17-18.
- [5] ZHUANG Leqiong. Analysis of the current situation and effective measures of electric power marketing[J]. Technology and Enterprise, 2012(17):94.
- [6] JIANG Yuan, WANG Xiaobing, LI xiaoming Discussion on the Status Quo of Electric Power Marketing System and the Construction of Information System [J]. Electronic world, 2020(15):88-89.
- [7] LI Yun, Li Anduo. Research on Power Marketing Decision System [J]. Computer Programming Skills and Maintenance, 2020 (05):16-17+29.
- [8] XIE Xuemei.Innovative Thinking on the Operation Mode of Electricity Checking and Collecting in Electricity Marketing [J].Low carbon world,2020,10(06):138-139.
- [9] YANG Fan, SUN Yizhen etc. Application of Digital Technology in Electric Power Marketing [J]. Integrated Circuit Application, 2019, 36(11):90-91.
- [10] Huang Xu.Research on the Intelligent System of Electric Power Marketing Accounting[D].North China Electric Power University(Beijing),2016.
- [11] Gao Yuan, Li Zhi, Liu Danhua, Cao Youxia, He Qingyuan. Design of automation and intelligent system for meter reading and accounting in electric power marketing[J].Modern Information Technology,2020,4(24):153-155.DOI:10.19850/j.cnki.2096-4706.2020.24.041.
- [12] Wu Chao. Research on the optimal basic electricity billing method based on data analysis [D]. South China University of Technology, 2017.
- [13] Zhang Lizi, Zhang Yimei, Ye Hongdou, Cheng Yu. Optional two-part electricity price pricing model and its method [J]. Automation of Electric Power Systems, 2016, 40(03): 59-65.
- [14] Liu Xin. Research on the Construction and Application of Electric Power Marketing Management Information System of Kaiping Power Supply Bureau[D]. South China University of Technology, 2011.

- 250
- [15] Flexible electricity bill calculation engine-Introduction to SAP IS-U/CCS billing engine[J]. Power Information, 2006(11):31.
- [16] YIN Shiming, Introduction to SAP Utility Solutions [J]. Power Information, 2004(07):81.
- [17] YANG Di,GE Yunlong etc. Construction of an intensive management and control platform for the whole business of electric power marketing[J]. Hebei Electric Power Technology, 2019, 38(06):14-16+43.
- [18] TANG Zhi,MU Hongmei.Systematic Analysis of Power Marketing Network in the 21st Century[J].Silicon Valley,2011(02):2.
- [19] Lu Jianhua, Zheng Yi.SAP Public Utilities Industry Marketing Solutions [M] Beijing: Tsinghua University Press, 2014:235.
- [20] LIU Yuxi, OUYANG Hong, LI Gang, ZHENG Qian, HU Ran, WANG Faen. Design of Public Information Model of Terminal Equipment of Business Distribution Network Based on IEC-CIM[J]. Smart power, 2019, 47(02):75-81.