Research on Robotic Process Automation Application in Electricity Charge Settlement for Distributed Photovoltaic Power Generation

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Abstract: Distributed photovoltaic power generation (DPPG) directly supplies power to users nearby, which is conducive to expanding the scale of renewable energy utilization, and is helpful to achieve the goal of "carbon peak and carbon neutrality". DPPG electricity charge settlement, with the characteristics of large business volume, strong regularity, high repetition, cumbersome manual operation and high error rate, is the typical business scenario for introducing modern information technology to carry out management innovation. Facing the whole process of DPPG electricity charge settlement, starting from business process analysis and optimization and redesigning, the paper introduces robotic process automation (RPA) to build a settlement model of "intelligent robot + personnel + information system", and provides inspiration and reference for improving the efficiency of electricity charge settlement.

1. Introduction

Distributed photovoltaic power generation (DPPG) directly supplies power to the users nearby, which is conducive to improving energy utilization efficiency and expanding the scale of renewable energy utilization. Vigorously developing a new energy power system with a high proportion of DPPG connected to the grid, is an important way to facilitate the realization of the goal of "carbon peak and carbon neutrality" [1]. In recent years, with the advancement of technology in related fields, cost reduction, capital follow-up, and the active support of policies that encourage the development of renewable energy, DPPG has developed rapidly [2]. Facing the challenges brought by the growing number of projects, and the huge, repeated, and cumbersome DPPG electricity charge settlement business, how to use modern information technologies to improve the efficiency of settlement, become hot issues of common concern in the field of power generation financial management [3-5].

Artificial intelligence (AI), as a research and development theory, method, technology and applied science, that can simulate, extend and expand human intelligence, has developed into a multidisciplinary technical field [6-7]. Robotic Process Automation (RPA) belongs to the classification of intelligent robots under the genre of human behaviour simulation methods. Its automated process application based on business logic and rule control can emulate the interaction process between humans and computer information systems as virtual employees, and effectively handle repetitive, rule-based tasks, so that humans can focus on other tasks of emotions, intelligence, reasoning, and judgment [8-9]. RPA runs on the top of the existing software, has non-embedded features, and
automatically executes low-value-added process-oriented tasks based on desktop records \cite{10}. Its deployment does not affect the original IT infrastructure, and can realize the integration of heterogeneous systems without adding interfaces \cite{11}. At the same time, the operation process of RPA can be strictly recorded and monitored without worrying about information security issues \cite{12}. These notable features provide strong support for innovation in the field of financial management.

The application of RPA in the field of financial management is compatible with the application basis such as standard processes, structured data, and stable operating environment \cite{13}. DPPG, due to its multi-level classification, phase subsidy policy, is the most complicated type of electricity charge settlement mode in distributed power generation. This paper is oriented to the whole process of electricity charge settlement for DPPG, starting from business process analysis and reengineering, introducing RPA to build a settlement mode of "intelligent robot + personnel + information system", to improve the efficiency of electricity charge settlement for DPPG, and reduce personnel costs.

2. Problems in Electricity Charge Settlement for DPPG

Electricity charge settlement for DPPG refers to the settlement services of subsidized electricity measurement and subsidy fund for DPPG projects listed in the renewable energy subsidy catalogue. Traditional business process of electricity charge settlement for DPPG, consists of 11 links: subsidy project integration, subsidy project maintenance, settlement data integration, settlement data confirmation, settlement voucher generation, settlement voucher review, fund payment initiation, fund payment review, payment voucher generation, payment voucher review, and payment information return.

In recent years, DPPG has achieved explosive growth in China. In 2019, new installed capacity of DPPG was 12.2 million kilowatts. As of the end of 2019, the cumulative installed capacity of DPPG was 62.63 million kilowatts, of which household photovoltaic power generation has become a new force. In 2019, the cumulative installed capacity of household photovoltaic power generation projects included in the national financial subsidy scale was 5.31 million kilowatts, accounting for 43.5% of all new installed capacity of DPPG \cite{14-15}. Incidentally, the settlement is facing great challenges:

First, the rapid increase in the number of projects has led to a continuous increase in the settlement business volume. Accompanied by the development of distributed photovoltaic business, the workload of electricity charge settlement, invoice issuance, subsidy settlement and issuance has increased dramatically. Taking the operating area of State Grid Corporation of China as an example, the settlement data is issued by the marketing department. After receiving the data, In accordance with the settlement and payment requirements, the financial department check, review, sign, and pay online for account information one by one. During the payment, the marketing department also needs to carry out work such as issuing paper invoices, verifying invoices from account to account, and verifying settlement data. When household power supply projects account for more than 80% and continue to expand, the workload is huge, and the personnel cost of electricity charge settlement continues to rise.

Second, the repetitive workload of low value-added, such as manual verification of online and offline documents and invoice, is large and error-prone, and the risk of complaints is high. Also take State Grid Corporation of China as an example, during the settlement process, the financial department obtains the paper electricity charges, confirmation receipts, and paper invoices provided by the marketing department, and manually checks with the online data of the financial system. Various information such as power generation amount, settlement amount, electricity charge, state subsidy amount, and provincial subsidy amount, need to be checked individually. If there is a tail difference record found during the check, the cost or tax tail difference must be adjusted item by item, and then the settlement confirmation will be carried out; if the data is found to be inconsistent, the marketing department must be notified to go through the refund and compensation process. At the same time, the settlement data is issued on a monthly basis, the single settlement amount is small, the number of transactions is large, the manual verification links are many, and it is easy to make mistakes. It is urgent to replace manual personnel by technical means, and undertake the repetitive work with clear rules, to improve the data quality, efficiency and reduce the risk of complaints.
3. Business Process Redesign of Electricity Charge Settlement for DPPG

In order to optimize of the electricity charge settlement process for DPPG based on RPA, this paper comprehensively sorts out and analyzes the traditional settlement business process, according to the principles of whether the business volume can be reduced, whether the business unit cost can be reduced, and whether the business efficiency can be improved, combined with the standardization, structuring and security requirements of each process link, the original 11 links are integrated, optimized and redesigned into 6 links shown in table 1, and lays the business foundation for the settlement mode of "intelligent robot + personnel + information system" based on RPA.

| No. | 11 links before optimization | Main business content | optimization or not | 6 links after optimization |
|-----|-----------------------------|-----------------------|---------------------|---------------------------|
| 1   | Subsidy project integration | Integrate supplementary information from external information systems | Y | Project subsidy |
| 2   | Subsidy project maintenance | Update subsidy project information | N | standard solidification |
| 3   | Settlement data integration | Get a list of marketing electricity amount and electricity charges | N | Settlement data integration |
| 4   | Confirmation of settlement data | Online and offline data are checked, and the marketing department is notified to return and make up for inconsistent data | Y | |
| 5   | Settlement voucher generation | Check the consistency of the paper invoice data with the system, settle the consistent data and generate vouchers, adjust the cost or tax tails; notify the marketing department to making up for inconsistent data | Y | Settlement voucher processing |
| 6   | Settlement voucher review | Login the system, open the to-do list vouchers to conduct audits | Y | |
| 7   | Fund payment initiation | For items that have been settled and payable, to initiate payment applications | N | Fund payment initiation |
| 8   | Fund payment review | Follow the management of online payment of funds, to approve | N | Fund payment review |
| 9   | Payment voucher generation | After the payment, the certificate is made manually one by one or in batches | N | |
| 10  | Payment voucher review | Review the basic information of payment vouchers one by one | Y | Payment voucher generation |
| 11  | Payment information return | After the payment, the payment status is fed back to the marketing management information system | Y | |

4. Development and Application of Intelligent Settlement Robot based upon RPA——Taking Electricity Charge Settlement for DPPG in Company Z as An Example

4.1. Introduce RPA to Develop Intelligent Settlement Robot

Company Z is a power grid enterprise with the construction and operation of power grids as its core business. It has 15 directly affiliated units, 11 prefecture-level power supply companies and 64 county-level power supply companies, and manages more than 180,000 household photovoltaic projects. In the traditional model, the electricity charge settlement for DPPG involves two departments: finance and marketing. Under the conditions of informatization, the electricity charge settlement needs to
operate across the financial management information system (FMIS), marketing management information system (MMIS), and other information systems. Project information maintenance, data verification, business approval and other tasks take up a lot of manpower, and the settlement efficiency is low.

Company Z introduces RPA in the mode of "intelligent robot + personnel + information system" (figure 1), to assists in processing electricity charge settlement for DPPG:

Link 1: Subsidy standard solidification. The intelligent robot is used to maintain basic information in the FMIS according to the rules, such as subsidy standards at all levels and stages, bank inter-bank numbers, and other information. Financial personnel only need to check from time to time, to confirm the data update.

Link 2: Settlement data integration. After obtaining the electricity charge list from the MMIS integrated, the intelligent robot enters the FMIS, reads the settlement information to be confirmed, uploads the settlement ledger according to different project types, and checks with FMIS. After the verification is completed, the results will be automatically downloaded, and emailed back to the marketing department.

Link 3: Settlement voucher processing. The intelligent robot obtains the consistent records, performs settlement processing in batches, generates settlement vouchers, and transmits them to reviewers. The intelligent robot logs in FMIS, judges and obtains the settlement voucher according to the rules, and completes the review.

Link 4: Fund payment initiation. After the payable data, marketing data, and invoice data are all checked and settled, the intelligent robot logs in FMIS, initiates the payment, and sends the result email to the marketing department.

Link 5: Fund payment review. The intelligent robot checks the integrity, reasonableness, compliance, abnormal supplier status, budget execution status, etc. of the payment records that have been initiated, and performs warning signs or no payment signs on records that do not meet the inspection specifications. The financial personnel directly electronically sign and confirm the records that meet the requirements.

Link 6: Payment voucher generation. The intelligent robot logs in FMIS to obtain payment records, executes generation of payment vouchers for successful payment records, and transmits them to reviewer. The intelligent robot determines to obtain payment vouchers, completes the review, and feeds the results back to MMIS.

4.2. Application of Intelligent Settlement Robot based on RPA
The operating architecture of the intelligent settlement robot in company Z is shown in figure 2. It consists of three parts: the robot client, the robot operating platform, and the robot monitoring service.
Among them, the robot client provides functions such as scene recording, custom development, running debugging, visual design, template management, import and export, capability enhancement, driver enhancement and other functions, to support scene design and development management; The robot operation platform provides functions such as human-computer interaction rule engine, process engine, secure storage, screen processing, mail processing, intelligent recommendation, robot driving, etc., to support robots to perform interaction and other automatic operation in multiple scenarios; The robot monitoring service provides functions such as snapshot playback, result viewing, log query, status monitoring, warning settings, abnormal monitoring, safety audit, breakpoint operation, etc., to provide real-time tracking records of the whole process for ensuring the normal operation of robots.

Company Z applies intelligent settlement robots to take advantage of 7*24 hours of uninterrupted work, non-interference with users, and multi-task operation. With the model of “intelligent robot + personnel + information system”, it effectively solves the aforementioned problems in electricity charge settlement for DPPG. The comparison of business operation efficiency before and after application is shown in table 2. The advantages of intelligent settlement robot are very obvious.

### Table 2  Efficiency comparison before and after application of intelligent settlement robot

| Link                  | Before                                      | After                                      |
|-----------------------|---------------------------------------------|--------------------------------------------|
| Settlement data verification & voucher generation | Manually checks data in FMIS and the offline marketing data, 10,000 transactions per month, 0.5 minutes per transaction, and it takes 5,000 minutes per month | The robot completes the settlement data verification, generates and transmits the voucher. only inconsistent records need to be manually processed, and the manual time is 60 minutes per month |
| Settlement voucher review | Manual review 50 settlement vouchers per month, 1 minute per voucher, and it takes 50 minutes per month | The robot automatically completes the credential review work |
| Fund payment initiation | Manually initiate 2000 payment per month, each 0.1 minute, and it takes 200 minutes per month | The robot initiates the payment and feeds the results back to the marketing department. Manual time is 10 minutes per month. |
| Fund payment review   | Manual review 2000 transactions per month, 2 minutes per transaction, and it takes 4,000 minutes per month | The robot reviews all except for records signed and confirmed. Each takes 0.1 minutes, and it takes 200 minutes per month. |
| Payment voucher generation | Manual review 50 payment vouchers per month, each takes 1 minute, and it takes 50 minutes per month | The robot automatically completes the credential review work |
5. Conclusion
Intelligent robots based upon RPA, as virtual personnel, have significant advantages in replacing manual basic accounting work with strong rules, high repetition, large workload, and low value-added. On the basis of optimizing and redesigning the business process of electricity charge settlement for DPPG, the development and application of intelligent settlement robots based on RPA can greatly improve the efficiency of settlement, reduce the risk of manual errors, improve data quality, save personnel costs, and effectively support financial personnel shift their energy to management accounting with more value-added, so as to unleash the potential of personnel while improving business efficiency.

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