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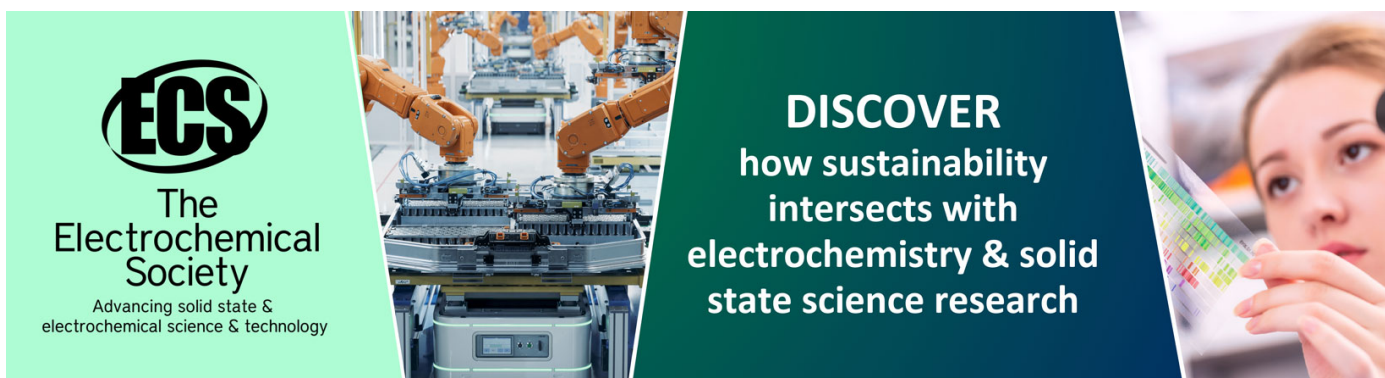
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Construction and Application of Scheduling Model of Power Grid Infrastructure Project Based on Delegate Power and Optimize Service Policy

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Abstract. In order to adapt to the reform of transmission and distribution price, implement the company's requirements of the policy of Delegate Power and Optimize Service, realize the precise investment of power grid and help the high quality development of power grid. It is urgent to explore a scientific and effective method of project schedule, assist the grid investment decision-making, and improve the level of investment plan management.

1. Research Background

With the further promotion of power system reform and the deepening of transmission and distribution price reform, grid investment should match the growth of electricity sales, and at the same time be linked with the level of transmission and distribution price, forcing grid companies to pay more attention to the efficiency and efficiency of grid investment. At the beginning of 2019, State Grid Corporation put forward the basic path of the development strategy of the new era "one lead, three changes", and emphasized the strategic orientation of the grid "high quality, high efficiency and sustainable development", strengthening precise investment, stable operation, and promoting the transformation of power grid development mode from scale expansion type to quality benefit type. At the same time, the company implements the policy of Delegate Power and Optimize Service (DP&OS), and expands the scope of material agreement inventory procurement, which will greatly shorten the period of material supply and have a great impact on the key milestone node arrangement of power grid infrastructure project and the preparation and adjustment of annual investment plan.

In the above context, investment plan management is the primary link of the implementation of power grid infrastructure projects, and the project implementation schedule is the basis for the rational preparation of the annual investment plan. Currently, the project implementation schedule is lack of scientific quantitative tools and means ^[4]. How to adapt to the transmission and distribution price reform, implement the requirements of the company's DP&OS policy, realize the precise investment in the power grid, and help the high-quality development of the power grid, it is urgent to explore a



scientific and effective project schedule method, assist the power grid investment decision-making, and improve the lean level of investment plan management ^[7].

2. Analysis on the Node Law of the Main Schedule of Power Grid Infrastructure Projects

The main implementation schedule nodes of power grid infrastructure project include key progress nodes such as feasibility study approval, demand submission, material bidding, construction bidding, contract signing, project commencement, civil construction (foundation construction), equipment installation (tower construction), equipment commissioning (stringing construction), production, etc ^[6]. Based on the big data of development, construction and materials, the timing rules of key milestone nodes of power grid infrastructure projects with different voltage levels and material procurement modes are comprehensively combed and mined to support the determination of key parameters for the construction of project milestone scheduling model ^[3].

2.1. Time Sequence Analysis of Material Key Nodes

Through sorting out the changes of the company's DP&OS policy on the scope of material procurement mode, clarifying its impact and transmission mechanism on the arrangement of key milestone nodes and annual investment plan of power grid projects of different voltage levels, and in-depth analysis of the timing rules of milestone nodes related to the material chain.

2.1.1. Study on the influence of the Policy of DP&OS on the material chains. In 2019, the company implemented the DP&OS policy and expanded the scope of agreed inventory procurement, including 110 (66) kV and below equipment and 220kV and below materials into the agreed inventory procurement. The transformation of procurement mode of 110kV equipment and 220kV materials will greatly shorten the period of material supply and greatly affect the arrangement of key milestone nodes of materials ^[8].

Table 1. The influence of the policy of DP&OS on two material procurement modes in 2019.

Voltage Grade	Supplies	Procurement Form	The Influence of the Policy
35 kV, 110 (66) kV	Equipment	AIP	From centralized procurement (CP) to agreed inventory procurement (AIP), the supply cycle of materials is greatly shortened, which is only affected by the production cycle and delivery of materials.
	Material	AIP	
220kV	Equipment	CP	No influence
	Material	AIP	From centralized procurement to agreed inventory, the supply cycle of materials is greatly shortened, which is only affected by the production cycle and delivery of materials.
500 kV and above	Equipment	CP	No influence
	Material	CP	No influence

2.1.2. Analysis on the business law of the whole process of material chain. By cooperating with the material department, this paper combs the differences of the key milestone nodes and the timing rules of each link between the centralized procurement and the agreed inventory procurement modes, and investigates and analyzes the procurement batch arrangement rules over the years, so as to lay the data and theoretical foundation for the project milestone scheduling.

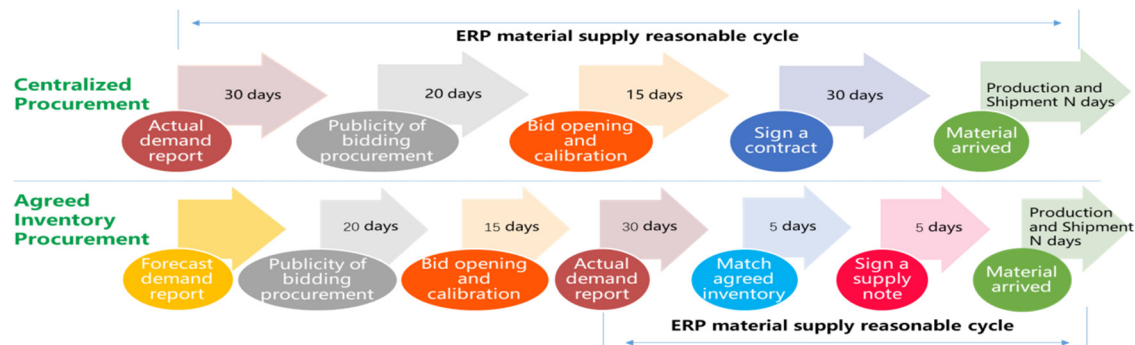


Figure 1. Schematic diagram of key milestone node arrangement of materials in different procurement forms.

2.2. Analysis on the Law of Construction Period

2.2.1. Overall project duration analysis. In order to carry out the project level construction period research, State Grid Hunan Electric Power Co., Ltd. collected the data of commencement time and completion time of power grid infrastructure projects from 2016 to 2019, and analyzed the construction period characteristics of different voltage levels and different construction properties from commencement to completion.

▪ Sample item description.

The development department has offline derived the main progress responsibility target data of grid infrastructure projects from 2016 to April 2019. There are 703 sample projects of grid infrastructure projects in total, and 575 sample projects excluding abnormal values (except for missing data and maximum and minimum values).

▪ Project duration analysis.

According to the sample data, the planned duration of power grid infrastructure projects with different voltage levels is analysed, the average planned duration of 110kV new project is about 10 months, the average planned duration of expansion project is about 6 months, and the average planned duration of transformation project is about 8 months. The average planned duration of 220kV new project is about 12 months, that of expansion project is about 5.5 months, and that of transformation project is about 10 months. The average planned construction period of 500kV new project is about 12.5 months, that of expansion project is about 9.6 months, and that of transformation project is about 10 months.

Table 2. Planned duration of projects with different voltage levels and construction properties. (Month)

Voltage Grade	New Project			Expansion Project			Transformation Project		
	MIN	MAX	Average	MIN	MAX	Average	MIN	MAX	Average
110kV	5.03	20.27	10.06	5.03	9.13	6.06	5.10	15.87	8.45
220kV	5.30	23.37	11.53	5.10	6.63	5.53	5.40	16.90	9.79
500kV	6.40	18.23	12.47	5.93	21.33	9.57			

2.2.2. Analysis of single project duration. In order to understand the characteristics of single project construction period of State Grid Hunan Electric Power Co., Ltd., according to the user-defined query of the Infrastructure Management and Control System, the data of single project's phased construction period covers 620 projects from 2016 to 2019. Among them, there are 230 substation projects, 87 after removing invalid and abnormal data, 390 line projects and 187 after removing invalid and abnormal data. The analysis of the above samples is as follows:

▪ Analysis on the construction period of substation project.

According to the above samples, the planned construction period, actual construction period and the comparison between them are analysed. Observing the figure below, it can be found that the actual

construction period of 110kV new substation project is 9 months, and that of 220kV new substation project is 12 months, which are basically consistent with the planned construction period.

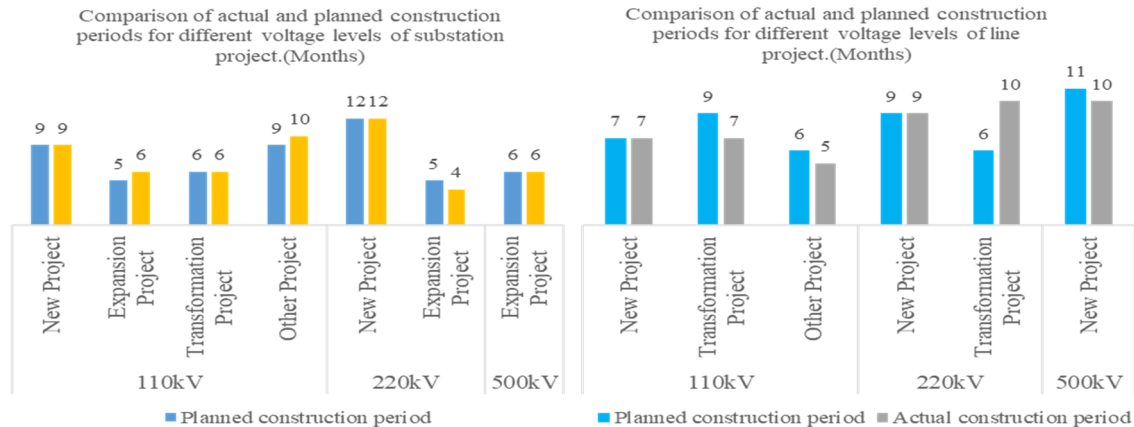


Figure 2. Comparison of actual and planned construction periods for different voltage levels of substation project.

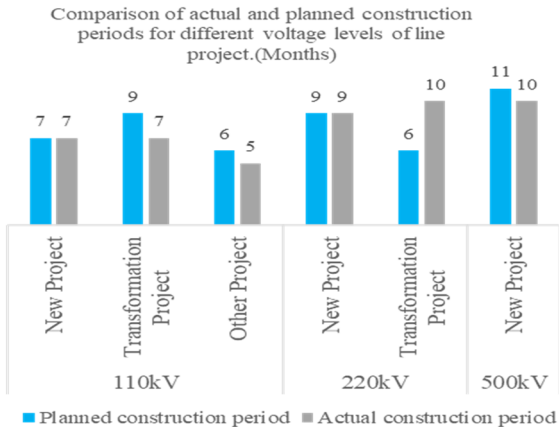


Figure 3. Comparison of actual and planned construction periods for different voltage levels of line project.

▪ Analysis on the construction period of line project.

According to the above samples, the planned construction period, actual construction period and the comparison between them are analysed. Observing Figure 3, it can be found that the actual construction period of 110kV new line project is 7 months, and that of 220kV new substation project is 9 months, which are basically consistent with the planned construction period; the actual construction period of 500kV new line project is 10 months, one month ahead of the planned construction period.

2.2.3. Analysis of single project stage construction period. In order to study the phased construction period of the main single project, State Grid Hunan Electric Power Co., Ltd. derived the actual start time and end time of the construction milestone stage from the capital construction management and control system according to the user-defined query, and analyzed the duration rules of different voltage levels, construction properties and construction stages.

▪ Construction period analysis of new substation project.

It can be seen from the observation of the figure below that the actual construction period of the civil construction stage is about 3 months longer than the planned construction period, and the actual construction period of the 110kV and 220kV equipment installation stage and commissioning stage is basically consistent with the planned construction period. Therefore, the lag between the actual construction period and the planned construction period is usually caused by the lag of civil construction stage.

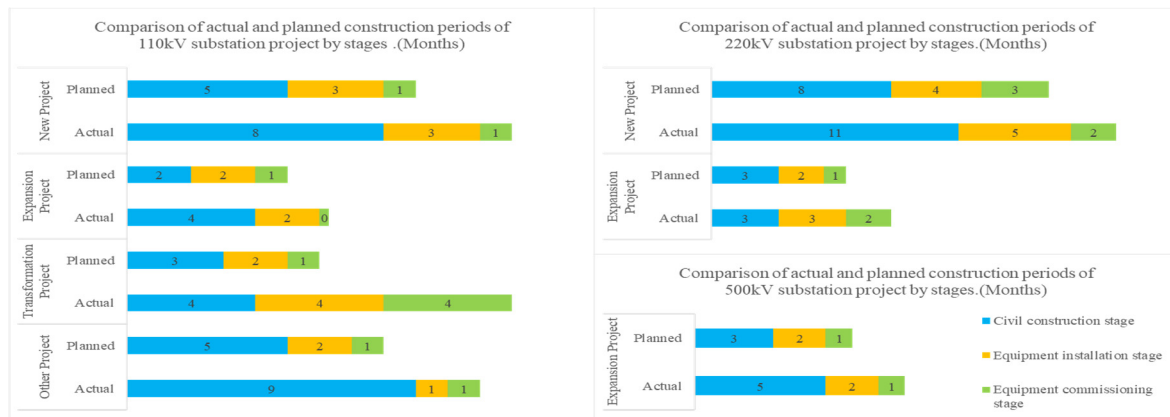


Figure 4. Comparison of actual and planned construction period of different voltage grade substation projects by stages.

■ Construction period analysis of new substation project.

It can be seen from the observation of the figure below that the actual construction period of the civil construction stage is about 3 months longer than the planned construction period, and the actual construction period of the 110kV and 220kV equipment installation stage and commissioning stage is basically consistent with the planned construction period. Therefore, the lag between the actual construction period and the planned construction period is usually caused by the lag of civil construction stage.

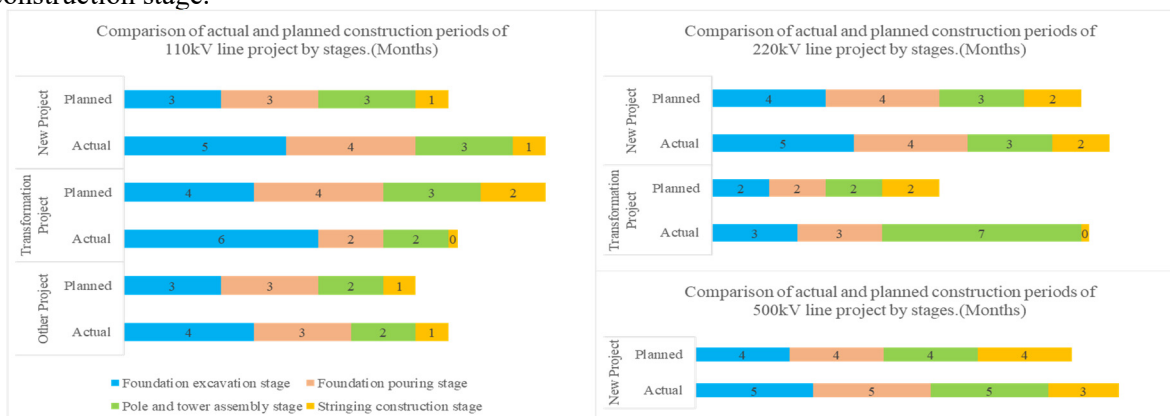


Figure 5. Comparison of actual and planned construction period of different voltage grade line projects by stages.

3. Construction of project implementation plan scheduling model

3.1. Build Project Milestone Schedule Model

Based on the above-mentioned time sequence law of the construction period of power grid infrastructure projects and key milestone nodes of material chain, the influence of the construction characteristics of power grid infrastructure projects, procurement batch, material delivery cycle and other factors on the arrangement of project investment time sequence is fully considered, and the project milestone planning and scheduling model of personnel, finance and material coordination is constructed by distinguishing centralized procurement and agreed inventory procurement mode. The model supports the project construction schedule, effectively solves the problem of Milestone Schedule of new projects, arranges the prior project investment, and scientifically coordinates the resource arrangement of investment, construction and materials. ^[1]

3.1.1. Analysis of single project stage construction period.

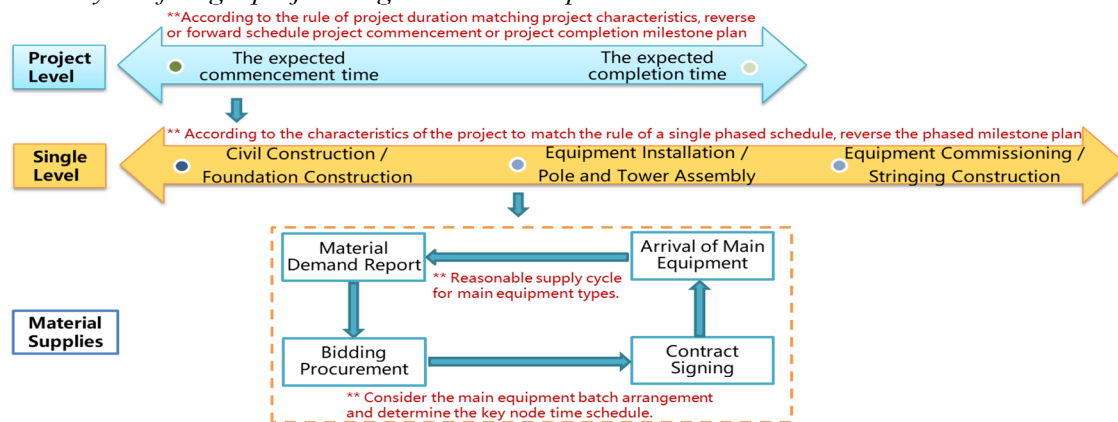


Figure 6. Schematic diagram of milestone scheduling of electricity grid construction project under centralized procurement mode.

Key milestone node scheduling is mainly divided into project level, single level and material chain level. After business research, Hunan company first combed the key milestone nodes involved in each level; secondly, clarified the sequence and influence sequence of nodes in each level; then, reasonably arranged the project milestone plan from the back to the front or from the front to the back based on the project, single item, milestone stage duration rule and material purchase batch, etc. Assuming that according to the power grid planning requirements, the expected production time of the project is known, taking the arrangement of milestones from the back to the front as an example, the specific scheduling steps are as follows:

The first step is to arrange the commencement milestone plan from the back to the front according to the expected completion time and the law of project duration.

The second step is to arrange the start and end time of the key milestone node according to the schedule law of the milestone node.

The third step is to get the equipment mobilization time according to the Milestone Schedule in the installation phase.

The fourth step is to deduce the reporting time of material demand from the back to the front according to the arrival time of materials and the reasonable supply cycle of materials.

The fifth step is to match the material demand submission time deduced from the back to the front with the purchase batch arrangement of State Grid Corporation to determine the main material demand submission time.

The sixth step is to determine the time of bidding, procurement, contract signing, material supply and equipment arrival according to the determined time of material demand submission and the material production and delivery cycle of different materials.

3.1.2. Analysis of single project stage construction period.

The arrangement of the agreed inventory purchase mode at the project level and milestone stage is the same as that of the centralized purchase mode. There are differences between them in the material chain business link, specifically: the agreed inventory bidding purchase and the contract signing node are advanced; before the actual commencement of the project, the actual material demand is reported, and the agreement is matched according to the frequency once a month Inventory: after the agreement inventory matching is completed, the purchase and supply order shall be signed with the merchant within 5 days. Based on the initial estimated material demand reporting time, the main equipment mobilization time shall be calculated forward.

The arrangement of the agreed inventory purchase mode at the project level and milestone stage is the same as that of the centralized purchase mode. There are differences between them in the material chain business link, specifically: the agreed inventory bidding purchase and the contract signing node are advanced; before the actual commencement of the project, the actual material demand is reported,

and the agreement is matched according to the frequency once a month. After the inventory and agreement inventory matching is completed, the purchase and supply order shall be signed with the merchant within 5 days. Based on the initial estimated material demand reporting time, the main equipment mobilization time shall be calculated from the front to the back.

After the above steps, the milestone plan nodes of centralized purchase and agreement inventory are respectively obtained. During the model calculation, the material procurement mode adopted by the project materials can be determined according to the voltage level of the project to be measured, and then different scheduling results can be selected.

3.2. Building a construction plan schedule model.

In order to get a more precise and accurate time schedule of electricity grid construction projects, the necessary construction time, construction process and process connection time of sub projects of electricity grid construction projects are fully considered, and the construction schedule model of electricity grid construction projects is constructed.

3.2.1. Milestone Schedule. Collect the construction period data of milestone nodes of completed and put into operation projects in recent years, and calculate the necessary construction period of milestone nodes by taking the average value of the collected sample data. According to the power grid planning requirements, the project start time or completion time is expected, and the necessary construction time of the estimated milestone plan is combined to arrange the milestone plan from the front to the back or from the back to the front.

3.2.2. Schedule of divisional works. To determine the planning schedule of divisional works, three scheduling model parameters need to be determined, which are construction process, process connection time and necessary construction time. According to the standard divisional works of each project type in the infrastructure management and control system and the construction content of each divisional works of the project, the construction process of the divisional works is sorted out; according to the standard project data, the process connection time and necessary construction time of the divisional works are calculated. Through the obtained parameters, schedule the subproject plan, and the specific steps are as follows:

Step 1: schedule the planned start time of divisional works one by one according to the determined process and process connection time of divisional works. The planned start time of divisional works = milestone node start time + process connection time.

Step 2: According to the obtained necessary construction time of the divisional works, the planned end time of the divisional works is calculated. The planned end time of the divisional works = the start time of the divisional works + the necessary construction period.

Taking the substation project as an example, the scheduling results of its construction schedule are as follows:

No.	Schedule Name	Plan Type	Planned Start Time	Planned End Time	Planned duration (days) (Taken is the minimum number of days)	Division Works Sequence	Process Connection Time	Whether to include Divisional Works (default is yes)
1	Project Start	Milestone Plan	2018-7-1					
2	Civil Construction	Milestone Plan	2018-7-1	2019-1-12	197	—	—	
3	Main control building (union building)	Divisional Work	2018-7-31	2019-2-16	201	2	30	Yes
4	Distribution system construction and construction	Divisional Work	2018-8-20	2019-1-16	150	2	50	Yes
5	Main transformer foundation and construction support	Divisional Work	2018-8-20	2019-1-25	159	2	50	Yes
6	Cable trench and cable tunnel	Divisional Work	2018-9-29	2018-11-29	62	4	90	Yes
7	Walls and gates (including external revetment, drainage ditch and guard room)	Divisional Work	2018-7-31	2018-12-27	150	2	30	Yes
8	Inside and outside road	Divisional Work	2018-7-11	2019-1-16	190	3	10	Yes
9	Outdoor site works	Divisional Work	2018-7-1	2018-11-5	128	1	0	Yes
10	Outdoor water supply and drainage and rainwater and sewage system buildings and structures	Divisional Work	2018-7-11	2018-12-6	149	3	10	Yes
11	Equipment Installation	Milestone Plan	2018-12-11	2019-5-25	166	—	—	
12	Installation of main transformer system equipment	Divisional Work	2019-2-16	2019-3-4	17	2	57	Yes
13	Installation of main control and DC equipment	Divisional Work	2019-2-15	2019-3-7	21	7	17	Yes
14	Installation of power distribution device	Divisional Work	2018-12-31	2019-1-25	26	4	3	Yes
15	Installation of reactive power compensation device	Divisional Work	2018-12-31	2019-2-5	37	3	1	Yes
16	Installation of station power distribution device	Divisional Work	2018-12-31	2019-1-31	32	6	19	Yes
17	Cable construction of the whole station	Divisional Work	2019-2-15	2019-3-17	31	5	0	Yes
18	Installation of lightning protection and grounding devices in the whole station	Divisional Work	2019-2-15	2019-3-21	35	1	36	Yes
19	Installation of electrical lighting devices in the whole station	Divisional Work	2019-2-15	2019-4-13	58	8	0	Yes
20	Equipment Commissioning	Milestone Plan	2019-4-24	2019-6-23	61	—	—	

Figure 7. Example of project construction schedule scheduling model.

4. Model Application Scenario

The above scheduling model of electricity grid construction project can be used to support three application scenarios: project milestone planning, annual investment planning and adjustment, and promotion of cross professional department collaborative management.

Application scenario 1: assist in project milestone planning. The model can support the planning of start and completion milestones of electricity grid construction projects, as well as the scheduling of milestone plans and construction schedules of specific projects, assist the scientific planning of resources such as investment, construction and materials, and improve the efficiency of resource use.

Application scenario 2: support the preparation and adjustment of annual investment plan. Based on the influence transmission mechanism and quantitative relationship among the project milestone plan arrangement, project construction progress and investment formation, it supports the preparation and rolling adjustment of the annual investment plan of the project, supports the scientific and reasonable prediction of the completion amount of the fixed asset investment, and improves the quantitative management level of the investment plan of the power grid [5].

Application scenario 3: Promote the collaborative management among multi professional departments. Combined with the auxiliary decision-making model of power grid investment plan, change the work mode of power grid investment plan management, establish a new mechanism of power grid investment plan management, realize the cooperation of development, infrastructure, finance and other professional departments, and provide support for deepening the application of the pre link of investment statistics [2].

5. Conclusion

Based on the historical data of electricity grid construction projects of development, construction, materials and other professional departments, the paper comprehensively combs and excavates the timing rules of key milestone nodes of electricity grid construction projects with different voltage levels and material procurement modes. The project fully considers the construction characteristics, procurement batch, material delivery cycle and other factors, establishes the relationship between construction, investment and materials, and constructs the project implementation schedule arrange the model, realize the reasonable arrangement of project milestone plan and construction schedule, assist the scientific overall arrangement of resources such as investment, construction and materials, and improve the efficiency of resource utilization.

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