



جامعة الجميع الذكية
EVERYONE'S SMART UNIVERSITY

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Section

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Advanced Project Management

Instructions:

- ☐ يغلق الواجب يوم الإثنين ١ مارس في تمام الساعة ٩ مساءً.
- ☐ الواجب سؤال واحد مقالي من ٤ درجات.
- ☐ الإجابة متاحة باللغة الإنجليزية أو اللغة العربية مع مراعاة أن تكون المصطلحات العلمية تكون باللغة الانجليزية.
- ☐ يرجى ضرورة التحويل إلى صيغة pdf بعد الانتهاء من الواجب ورفع على المودل.

Instructor's Name:

Eng. Amaal Aburumman

Building Electrical Substation

1-inteodction:

Nowadays the electrical power demand is increasing very rapidly. For fulfilling these huge power demands the modern time requires creation of bigger power generating stations. These power generating stations may be hydro – electric, thermal or nuclear. Depending upon the availability of resources these stations are constructed in different places. These places may not be nearer to load centres where the actual consumption of power takes place. So it is necessary to transmit these huge power blocks from generating station to their load centres. Long and high voltage transmission networks are needed for this purpose. Power is generated comparatively in low voltage level. It is economical to transmit power at high voltage level. Distribution of electrical power is done at lower voltage levels as specified by consumers. For maintaining these voltage levels and for providing greater stability a number of transformation and switching stations have to be created in between generating station and consumer ends. These transformation and switching stations are generally known as electrical substations.

A substation is a high-voltage electric system facility. It is used to switch generators, equipment, and circuits or lines in and out of a system. It also is used to change alternating current (AC) voltages from one level to another, and/or change alternating current to direct current or direct current to alternating current. Some substations are small with little more than a transformer and associated switches. Others are very large with several transformers and dozens of switches and other equipment.

Construction of electrical substation projects includes civil works and electromechanical works. Scheduling and optimization the execution processes of civil works are complex and challenging tasks . Construction of electrical substation consists of phases working in parallel to each other and each phase includes a group of buildings. All these buildings share resources at the same time (eg, equipment, labours and raw materials). The selection of resources is the most important part of scheduling and should be considered incongruence with site restrictions and the work to be undertaken (Jaskowski and Sobotka, 2006). As electrical substations projects are unique in nature, the creation of a schedule for construction tasks, should consider an array of conditions such as technological and organizational methods and constraints, as well as the availability or limitation of resource to ensure that a client's needs and requirements in terms of time, cost and quality are met (Zhou el al, 2013).

Substation construction scheduling is concerned with optimally sequencing activities over time and allocating resources accordingly. Construction of substations faces complicated time-cost-resource optimization problems. These multivariate problems require simultaneous minimization of total project duration and total project cost while considering issues related to optimal resource allocation and resource levelling. In other words, substation construction project scheduling should be performed under resource

constraints with considering flexibility for time and cost savings through proper resource allocation. However, conventional project scheduling methods and most notably, the critical path method (CPM) have limitations. The limitations are that they do not consider assigning resource availability constraints to project activities or the possibility of time and cost savings through changing project schedules and resource adjustments (Kim and Ellis 2010). The major problem is that the focus of these conventional methods is on local optimality at activity level and not on global optimality at project level; i.e., these methods are not capable of simultaneous time-cost-resource optimization (Ashuri and Tavakolan, 2015).

This paper presents simulation and optimization models for the civil works of an electrical substation using Anylogic software and a data base excel file for input data entry to estimate the time and cost of the substation using each model and determine the differences. The simulation model shows the real time sequence of events that the project would run through to finish all activities of substation using shared resources.

availability in resource pools as constraint, and maintaining different relationships between the activities. The optimization model is created on the same model using parameter variation experiment and genetic algorithm (GA) java code implemented using Anylogic platform. The objective function of optimization model is to minimize project time using resources allocation parameters as decision variables and maximum number of resources available as constraints. The model estimates the cost of the substation after each experiment (simulation and optimization) including direct cost and indirect cost, percentage of utilization of each resource (equipment and labours) and consumed amount of each material. The differences in time, cost and resource allocation between both models are discussed. Also, an analysis was created to present the variation in effect of parameters on project time and cost. The proposed model utilizes functions with double roles to perform actions or to obtain the result of function calculations.

Electrical substations are unique projects, consists mainly of the same buildings and components with the same design. Sometimes the areas of the buildings and number of components differ from substation to another according to the total area of the substation and the electrical power the substation is required to deliver. The scope of civil works includes all construction, finishing and sanitary works. The main components of an electrical substation are:

- Gas insulated switchgear (GIS) building, this building is designed to house the gas insulated switchgear and auxiliary equipment, distribution panels, cables and raceways, and the portion superstructure is serviced by a crane. The GIS portions are designed to accommodate the bus/breaker arrangement and the space requirements for maintenance area.
- Control building, it is also a single story reinforced concrete building of height less than GIS building. This building is designed to house medium voltage switchgear,

auxiliary transformers, batteries, power supply system, telecommunication system, and control and protection system;

- Switchyard portals foundations, these are concrete footings designed to carry out the steel structure of various apparatus for all switchyard equipment;
- The foundations of the outdoor main transformers, they are designed to carry the loading from the oil filled transformers with any additional loads due to transformers operation, seismic and other natural phenomes. There are two types of transformer's foundations; foundations for outdoor switchyard power system and foundations for switchgear power system;
- Fire walls, these walls are protection reinforced concrete walls constructed between every two transformers foundations;
- Underground reinforced concrete fire footings, they are constructed for outside galvanized steel firefighting water tank;
- The galvanized steel fence surrounds the outdoor switchyard and the outdoor transformers area and rested on concrete footings;
- Cable trenches, reinforced concrete trenches are required for installation of buried cables, conduits, piping, etc.
- Roads are required for operation and maintenance of the substation and to get easy access to any part inside the substation. Roads are divided into main roads and secondary roads;
- Firefighting buildings, they are reinforced concrete skeleton buildings with suitable area constructed to maintain firefighting system for transformers provided with all necessary equipment and accessories;
- Workshop building, it is a reinforced concrete building constructed for storage, maintenance and workshop works;

2. PREVIOUS WORK

A plethora of methods have been propagated to address the construction schedule and cost optimization problem, which can be categorized into four areas: heuristics, mathematical programming, simulation, and genetic algorithms (Bayraktar, 2006).

2.1 Heuristic methods:

Heuristic methods that generally do not have a mathematical background. Such methods do not guarantee optimal solutions (Feng et al, 2000). Prevalent heuristic methods include Fondahl's method (1961),

2.2 Mathematical methods

Mathematical programming methods use critical path method, linear programming, integer programming, or dynamic programming to find optimal solutions (Feng et al, 2000). Liu and Li (2003) developed a method to accommodate resource constraints and repetitive scheduling known as the Resource-Activity Critical-Path Method.

2.3 Simulation methods

Simulation modeling and visualization are increasingly used tools in the field of construction. Simulation modeling consists of creating a model that is the "imitation of the operation of a real-world process or system over time" (Banks et al, 2001). It takes data from the model creator, as input, based on historical data and assumptions. The model itself consists of logical relationships and processes defined by the modeler. The

output consists of results based on the interaction of the input data with the designed model. There are three main types of simulation which are discrete-event, agent-based and system dynamics (Zankoul et al, 2015).

2.4 Genetic algorithm (GA) methods

GA belongs to the larger class of evolutionary algorithms (EA) that solves optimization problems using techniques based on natural evolution. There are other members of EA such as genetic programming, evolutionary programming and evolution strategy. A GA can be defined as random searching algorithm which depends on the mechanism of natural selection and survival of the fittest solution. The three most important operators of GA are selection, crossover and mutation (Zhou et al, 2013).

3. METHODOLOGY

The simulation model of electrical substation is developed using AnyLogic software connected with data base excel file for input data entry. AnyLogic has been generally utilized in simulation for simplicity of model building, a visual model improvement environment, adaptability, and animation. The interesting adaptability of the modeling language empowers the user to capture the multifaceted nature and heterogeneity of business, financial and social systems to any craved level of detail. The graphical interface, apparatuses, and library objects permit user to rapidly show differing ranges, for example, assembling and logistics, business processes, human resources, purchaser and patient conduct. The object-oriented model outline worldview accommodates particular, hierarchical, and incremental development of expansive models.

Active objects can be used to model very diverse objects of the real world. These elements are shown in a palette view grouped by categories in a number of stencils (palettes) and libraries such as Agent, Presentation, State chart, Connectivity, Process Modelling Library and Pedestrian Library.

The substation model is built by discrete event simulation method. Discrete-Event simulation modeling also, referred to as "Process-Centric" in AnyLogic, consists of dividing a continuous process into discrete parts to simplify analysis. The process in question is modeled as a sequence of discrete events or activities. Entities arrive into the model at a certain arrival rate and go through its activities one at a time sequentially. The AnyLogic Process Modelling Library elements are used to build this model as it supports discrete-event, or process-centric modeling paradigm.

The execution process of civil works of the substation depends on dividing the total construction area into three zones (phases) working in parallel to each other as they are not related to or dependent on each other. Therefore, the model is divided into three zones; each zone includes a group of buildings which are related to the same construction area as following:

Zone 1: This zone is related to gas insulated switchgear area which includes GIS building and control building.

Zone 2: This zone is related to switchyard area which includes portals foundation, transformers foundations, fire footings, fire walls, chain link fences, cable trenches, main roads and secondary roads.

Zone 3: This zone is related to service buildings area which includes firefighting buildings, workshop, elevated tank, drainage tank and vehicles shed. Building the model goes through ten main stages as follows:

- Creating a data base excel file;
- Creating a new model called "OzModel";
- Creating a new java class "Util";
- Creating the flow charts diagrams of Zone 1 model- agent type;
- Creating the flow charts diagrams of Zone 2 model- agent type;
- Creating the flow charts diagrams of Zone 3 model- agent type
- Cost estimation of the substation (direct and indirect cost);

4-Results

The first step to run the model is to enter the input data of Elnabq substation in the data base Excel file. These data are the actual data of Elnabq substation. As mentioned previously in section 5.1, the bill of quantities, resources breakdown, unit cost of materials and indirect cost data are entered in sheet 1 of the excel file. The production rates of equipment and manpower crews, the maximum available number of resources for each zone, the number of resources needed by each building and unit cost per day for each resource are entered in sheet 2 of the excel file.

After running the simulation and optimization models for each zone and obtaining time and cost results, it can be observed that the time of Zone 1 model decreased from 390 days after simulation experiment to 350 days after optimization experiment, the difference in model time between both experiments is 40 days which is nearly 10.25% of the total time of Zone 1. For Zone 2 model, the time decreased from 238 days after simulation experiment to 215 days after optimization experiment, the difference in model time units between both experiments is 23 days which is nearly 9.7% of the total time of Zone 2. While the time in Zone 3 model decreased from 152 days after simulation experiment to 135 days after optimization experiment, the difference in model time between both experiments is 17 days, which is nearly 11.2% of the total time of Zone 3. As all zones work parallel to each other, this means that Zone 1 is the critical path and the total substation model time units decreased by 10.25% which is the value of Zone 1(see Table.).

TABLE. 1: Comparison between model time results after simulation and optimization experiments

Descriptio n	Time after simulatio n (days)	Time after optimizati on (days)	Reductio n in time (days)	Percenta ge of reduction in time	CPU time (seconds)
Zone 1	390	350	40	10.25%	2602.86
Zone 2	238	215	23	9.70%	2936.56
Zone 3	152	135	17	11.20%	3114.53
Total	390	350	40	10.25%	8653.95

5. CONCLUSION

Electrical substation construction projects are considered very important projects. An electrical substation is a subsidiary station of an electricity generation, transmission and distribution system where voltage is transformed from high to low or the reverse using transformers. Electric power may flow through several substations between generating plant and consumer, and may be changed in voltage in several steps. Scheduling and optimization the execution process of civil works of electrical substation are considered complex and challenging tasks. The electrical substation consists of several phases working in parallel to each other; each phase includes a lot of components and requires different resources which are shared by different buildings at the same time.

In this paper, two models are presented for electrical substation construction projects; a simulation model and an optimization model. The models are constructed by discrete event simulation method using Anylogic software. A data base excel file is constructed for input data entry. So, the model can be considered as a template for execution process of civil works of any substation project. The aim of the simulation model is to obtain the total time units and cost of the substation according to the maximum available resources specified by user and according to input data. The optimization model is built also on the same model by using parameter variation experiment and implementing genetic algorithm (GA) java code on a java class using Anylogic platform to obtain the minimum model time units, the optimum sequence of work corresponding to this time, the optimum resource allocation and the corresponding cost. The available resources and the resource parameters are considered the model constraints and decision variables respectively.

The models are tested on a real case study which is Gizan city center substation, located in gizaan city, KSA . The models demonstrate efficiency by attaining a reduction in model time units between simulation and optimization experiments of 10.25% and reduction in total cost of 4.7%. An analysis to determine the effect of each resource on reduction in cost is included. The analysis indicates that the resources that are related to concrete and skeleton activities are more effective on reduction in cost than finishing

6. REFERENCES

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