Revista de la *Universidad Politécnica* de Puerto Rico

Publicado semestralmente por la Universidad Politécnica de Puerto Rico para difundir los hallazgos de la investigación científica que en ella se hace

VOL. 5 JUNIO 1995 NÚM. 1

The development of my capstone design project

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Abstract

This article is the result of my Capstone Design Project, which I started during the summer of 1994. The main purpose of this course is to expose us to the ever changing and challenging world of the engineering design work. My project consists of the design for the electrical wiring of a hotel facility which I named Apolo Beach Resort (ABR).

El desarrollo de mi proyecto para completar los requisitos para el grado de bachiller en ingeniería eléctrica

Sinopsis

Este artículo es el resultado de mi proyecto para completar los requisitos para el grado de bachiller en ingeniería eléctrica. El proyecto se comenzó durante el verano de 1994. El propósito de este tipo de proyecto es exponer al estudiante al revolucionario mundo del diseño de ingeniería. Mi proyecto se basa en el diseño para el servicio eléctrico de un hotel, el cual he denominado Apolo Beach Resort (ABR).

Introduction

Exposing the student to the engineering design field has five different goals:

1. To apply already known concepts

   The theory studied in the classroom is of little or no use if we do not know when and how to apply it. With this work I had the opportunity to put in practice the principles learned in the classroom.

2. To behave with self-assurance

   In the engineering field one must learn to unfold and relate with other professionals. This project gave me a direct confrontation with this issue.

3. To learn the principles of project management

   A project is considered successful when it is completed on time and within budget, without sacrificing quality. Creating a comprehensive schedule is critical to the success of any project. To create a reliable schedule we must follow these four steps:

- Define project goals

- Develop a strategy
  This simply means defining how you plan to manage the project.

- Establishing a sequence
  The duration of each task and the order in which they must be performed.

- Define milestones
  These are checkpoints, or interim deadlines, that help you measure the progress of the project.

4. To use the benefits of Computer Aided Design programs

   The field of engineering is very demanding. To be competitive one must use computer programs to speed up the calculations and to reduce the possibility of errors.

5. To organize our work

   This project serves as an exercise to practice how to submit an idea in a simple, organized and convincing way so any reader can understand and approve it.

My project consists of the design for the wiring for the electric service of a hotel facility which I named Apolo Beach Resort (ABR). The hotel will have three floors, 60 rooms, a restaurant, a cafeteria, one tennis court, beach area, a swimming pool (15' x 30'), one infirmary room, one machinery room, one service room (storage), a laundry room, two public bathrooms, two hydraulic elevators and four public telephones.

A complete design is mainly composed of five stages: listing the project specifications, making the wiring layouts, electrical load analysis, selection of the electric service equipment and making a cost estimate.

After going through a brainstorming phase where I organized all the ideas, I developed a work schedule using the computer program Time Line. This schedule is the main time guide across my work.

The design

Listing the project specifications

This phase is very important because all the other steps depend on the information given here. With the aid of standards for architectural graphics I selected the dimension of all the hotel occupancies. Then listed all the electrical equipment used in the hotel. I searched for information on the electrical consumption characteristics of the listed equipment.

Making the wiring layouts

This step takes care of sectioning the load by location and assigning it to individual branch circuits in a specific distribution panel. For the wiring diagrams I needed the structural blueprints of the hotel. However, they were not available and I had to make them. I chose AutoCad, a well-known computer drawing program, for this time consuming task.

Electrical load analysis

This phase consists of the sum of all electrical loads connected to each branch circuit of each panelboard. After an extensive studying period I performed the electrical load analysis following the methodology explained in the National Electrical Code 1993 (NEC), a publication of the National Fire Protection Association that regulates electrical designs. The complete load analysis for the ABR took 64 pages and its outcome was that the total electrical load required by the hotel was 260.84 kVA.

Selection of the electric service equipment

In this phase we select the feeder, breaker and conduit for each branch circuit.This hotel has a substantial possibility of expansion (casino, night club, sauna, gymnasium and others). For that reason the selection philosophy employed in this design was to have the largest possible extra capacity for the least reasonable increase in costs.

To select the primary service voltage of the hotel a rate comparison between a 38 kV service and a 13.2 kV service was made. The results of this comparison are the following:

- General Service at Primary Distribution Voltage (GSP)

  Service: Alternating current, 60 Hz., 3 or 4 wire, three-phase, 13,200 V
  Rate: Monthly bill = $1,477.30
  Minimum monthly bill: $ 605.00

- General Service at Transmission Voltage (GST)

  Service: Alternating current, 60 Hz, 3 or 4 wire, three-phase, 38,000 V
  Rate: $ 1,662.59 (this rate is below the minimum)
  Minimum monthly bill: $ 2,375.00
  Monthly bill = $2,375.00

Comparing the two service rates, $1,477.30 for 13.2 kV and $2,375.00 for 38 kV, it is evident that the GSP (13.2 kV) is the one to choose.

Substation and auxiliary system capacity selection

As stated before, the total load is approximately 261 kVA. The substation capacity is determined by the sum of the capacities of its three transformers. For this load the first logical choice is to select three 100 kVA ($2672 each) transformers to obtain a total capacity of 300 kVA, which covers the load and give us an additional 15% capacity for future expansion. However, a value engineering shows that the best alternative is to select three 167 kVA ($3762 each, which is the next standard capacity) transformers, which give us a total capacity of 501 kVA. This capacity covers the load and gives us an additional 90% capacity for future expansion at a 41% increase in the previous option costs. This obeys the proposed philosophy of having the largest possible extra capacity for the least reasonable increase in costs (table 1).

Table 1. Substation costs

Transformer capacity (kVA)	Quantity	Total capacity (kVA)	Price	Total
100	3	300	$ 2,672.00	$ 8,016.00
167	3	501	$ 3,762.00	$ 11,286.00

Economic study

To compare both options, the selection of 100 kVA or 167 kVA transformers, an economic study employing the Straight Line Depreciation Method (SLDM) was performed. Both assets were compared for a 20-year period. Table 2 shows these results.

Table 2. Economic study comparing the option of 300 vs. 501 kVA

Transformer capacity (kVA)	Quantity	Book value (20 yrs)	Depreciation rate (%)
100	3	3005.33	3.13
167	3	4362.00	3.07

Because the 501 kVA option has the lowest depreciation rate, obeys the proposed philosophy and has the larger book value at the end of a 20-year period, this was the selected one.

Auxiliary system impact to the per room cost

The capacity of the auxiliary system was selected so that it can completely manage the load the substation handles (including the future expansion factor). Because 500 kVA is not a conventional value in auxiliary systems, the next standard capacity, 625 kVA, was selected.

- Generator set total cost
  (generator & transfer switch) = $ 85,440.00

- Generators set cost per room
  (85,440.00)/60 = $ 1,424.00

- Per room construction costs (without gen. set)
  (total cost will be presented later in this article)
  (578,547.94 - 85,440)/60 = $ 8,218.47

- Per room construction costs (including gen. set)
  (8,218.47 + 1,424.00) = $ 9,642.47

The increase of $1,424.00 in the per room cost is justified by the convenience of a continuous, uninterrupted service for the guests.

Esthetics and security as a selection factor

In all electrical design work, security plays an important role. In this project security was also considered. Some security elements are listed below:

- In the substation, the cubicles will be mechanically interlocked to prevent the opening of the door before a power shutdown.

- All receptacles installed within 6 ft of a sink, in bathrooms, in counter tops, in storage areas, and in the elevator pits shall have ground fault circuit interrupter protection for personnel.

- Smoke detectors were specified in all hazardous locations.

- Closed-circuit TV security system was stipulated in strategic positions.

Sometimes the selection of specific equipment or installation is mainly governed by esthetics (how it looks). In this design, several equipment pieces were selected in regard to esthetics. Some of them are listed below:

- Decorative ceiling and wall illumination fixtures.

- Decorative ceiling fans with lamp fixtures.

- An electric neon sign.

- Illumination of the two large lobby walls, which was done to illuminate the pictures hanged on them.

Protection equipment selection breakers and fuse coordination

Protection devices are important because they provide the safety for the personnel and the electric equipment.

Main primary fuses

The IEEE defines a fuse as "an overcurrent protective device with a circuit-opening fusible part that is heated and severed by the passage of the overcurrent through it" (IEEE 100-1984). A fuse is selected to operate at a specific current and at a certain time delay. Using the minimum melting time-current characteristic curves at 220 A (obtained from a short circuit analysis) and 0.35 seconds (21 cycles) the fuse unit selected is a 25E.

Main secondary automatic circuit breaker

A circuit breaker is a mechanical switch capable of interrupting fault currents and of reclosing. This device can be set to operate with a specific time delay. The selected secondary breaker rating, according to the NEC 1993 sec.215-3, 220-10(b), 230-42(a), 240-3, 240-6, is 800 A.

The main primary fuses were selected to operate at 0.35 seconds (21 cycles). The main secondary breaker must be set to operate before the main primary fuses. This is why the main secondary breaker should be set to 0.25 seconds (15 cycles) (Table 3). The panelboard breakers should open before the main secondary breaker, so the panelboard breakers must be set to instantaneous trips.

Table 3. Protection equipment coordination

Description	Operation time
Main primary fuses	0.35 seconds (21 cycles)
Main secondary breaker	0.25 seconds (15 cycles)
Panelboard breakers	Instantaneous

Grounding conductor selection

From the protection of the secondary bus we know that the rating for the automatic overcurrent device is 800 A. The National Electrical Code 1993 in the section 250-95 states that the grounding conductor shall be sized on the basis of the ampere rating of the overcurrent device protecting the circuit conductors in accordance with the table 250-95, the grounding conductor shall not be less than the size specified in the table 250-95. For an overcurrent device of 800 A, the minimum grounding conductor is #1/0, but for additional protection the next size, #2/0, was selected.

According to the section 250-91(b) of the National Electrical Code 1993, it is permitted to use electrical metallic tubing as the grounding conductor for equipment. Knowing that this advantage will eliminate the need (and costs) of long grounding wires, electrical metallic tubing was selected for this project.

The ABR substation (with its load connected) was simulated using a specialized computer program designed for the planning, evaluation and reporting of power distribution systems. The Dapper module of the Power Tools System from SKM Systems Analysis, Inc., was the computer program used.

Three studies were performed to the hotel substation. They are listed and described below:

- Demand load analysis

  This report tells us the total amount of power required from each bus. With this information the program determines each feeder size.

- Feeder and transformer size analysis

  This report helps select the correct size for feeders and the capacity of transformers.

- Load flow and voltage drop analysis

  This analysis reports the magnitude and direction of the power flow from one bus to the other and the voltage drop between them.

Results

The following is a discussion of the outcome of the studies realized with the Dapper module of the Power Tools System. Comparing the results obtained from the electrical load analysis and the ones from the demand load analysis we verified that the calculations realized are correct (Table 4).

The feeder and transformer size analysis was of little or no use to us because the THHN insulation type is not found in the libraries of Power Tools system. This insulation has a temperature rating of 90 degrees Celsius, which is appropriate for the climate of Puerto Rico. The program selected the

THWN insulation type that has a temperature rating of 75 degrees Celsius, which is unsuitable for our weather. The difference in insulation types makes it impossible to compare feeder selections because the insulation type directly affects the conductor ampacity and, therefore, its size.

Table 4. Results obtained with the Dapper module of the Power Tools System

Panelboard	Load analysis (Amperes)	Power Tools (Amperes)
MDPE1	60.26	60.3
MDPE2	92.03	92.0
MDPS1	65.51	65.5
MDP1	276.10	276.1
MDP2	105.39	105.4
MDP3	124.71	124.7
PDP#1	368.13	368.1
PDP#2	355.88	355.9

The load flow and voltage drop analysis tells us that the design meets the National Electrical Code voltage drop regulations because the largest voltage drop encountered was of 2.6%. According to Section 215-2(b)(FPN #2) of the NEC 1993, the maximum voltage drop shall not exceed 5%.

Making a cost estimate:

The report of the costs of the project consists of two mayor parts: the costs associated with the design and the construction costs, which include manpower and materials. The design costs are included as an overhead in the construction costs (Table 5).

Table 5. Construction costs

Description	Amount ($)
Conduits	39,948.45
Conductors	23,102.60
Excavations	918.32
Ground Rod	188.40
General Equipment	219,150.08
Breakers	2,908.20
Panelboards	21,676.00
Substation	34,098.00
Auxiliary system	85,440.00
Subtotal	427,430.05

The amounts used were taken from Means Electrical Cost Data, Westinghouse Quick Selector Catalog #25-000 and electrical wholesalers/distributors such as Roger Electric Co.,Inc., ASFA, Inc and West India Machinery and Supply Co.

Field & Office Overhead (15%):

Design cost = $ 40,000.00
Overhead = $ 24,114.51

$ 64,114.51

Subtotal = $ 491,544.56

Insurance (2%) & Municipal Taxes (5%) = $ 34,408.12
Subtotal = $ 525,952.68

Profit (10%) = $ 52,595.27
Total = 578,547.94

Comparing the design and the construction costs, we see that the design cost constitutes a 6.91% of the construction cost, which is acceptable according to industry standards.