ELG4125

Case Study of Multiple Submissions

Power System Planning and Design of

Power Plant, Transmission and Distribution Systems, Substations, Protection and Monitoring Systems, and Distributed Generation

Based on Optimization of

Electrical, Mechanical, Environmental, and Economic Factors

Final Submission

Submit a 10-page portfolio on the day of the final exam.

Case Study (Statement) (Total: 90 marks)

- Connect a large four-reactor nuclear generation plant (750 MW per reactor, constant output) via 500 kV two parallel transmission lines with a large city (modeled as an infinite bus) which is 400 km away from the power plant.
- At the midline between the nuclear reactors and the large city, a transformer is installed at the midline bus to supply a different town with 120 kV. This town is 10 km away from a proposed connection point of a wind farm with a capacity of 100 MW.
- The town bus is supplied with 300 MW with a constant 50 MVAR reactive power demand and a 100 MVAR (nominal) shunt capacitor installed initially.
- **Provide graphical details of the entire power system.**

Task 1: Nuclear Power Plant (10 marks)

- Design the above power plant system to meet current and future requirements of load growth, taking into consideration the following:
  - Establish the plant design envelop which comprises the design basis and complementary design features.
  - Specify and size drivers.
  - Specify and size generators.
  - Specify and size transformers.
  - Specify and size all other related equipment.

Task 2: Transmission Line (10 marks)

- **Transmission Line Characteristics:** Estimate the performance of the system in terms of efficiency and voltage regulation. Set up specifications for the transmission line in terms of conductors (resistance; inductance; capacitance); insulators; towers; line loadeability, etc. Include appropriate figures for towers and insulators. Identify the three-phase line as single circuit or double circuit. You may use tables A.3 and A.4 from the textbook or other sources for the above reason.
- **Transmission Substation:** Include site selection, transformer power ratings, turns ratio, grounding; configurations, efficiency; components of each substation with specifications. Include figures where appropriate.

Transmission Line Design Considerations

- Select a suitable conductor for the overhead transmission line: ACSR; AAAC; ACAR, or others. See Section 4.1 of the textbook.
- Select a suitable tower: number of circuits; number of conductors per phase; type and details of insulators; tower/line protection specifications; and characteristics of shield wires. See Table 4.1!
- Estimate the current that flows in each conductor. Based on this current, the size of the conductor can be estimated. Then use tables to find the parameters such as R, L, and C, then to find Z and Y.
- Build your transmission line model to find ABCD constants.
- Find V_s, I_s, V_r, I_r of each section of the transmission line.
- Find the efficiency and voltage regulation.

Task 3: Protection and Control (10 marks)

- **Based on the transmission system given in Part 1, provide all protection, control, and monitoring features taking into consideration the following facts:**
  - Provide appropriate protection zoning (see section 10.8).
  - Provide techniques to protect the system against faults and lightning effects.
  - Provide type and rating of protection equipment for power plant, substations, buses, and transmission lines (use Table 10.2; Sections 10.9-10.12).
  - Provide circuit diagrams of the proposed relays (for example, impedance and differential).
  - Read the case study given in Chapter 10 (pp. 518-524) in regard to communication technologies and provide the key features and trends (types; modulation techniques; drawbacks) of broadband over power line (BPL).
  - Propose and describe shunt connected FACTS devices STATCOM and SVC .
  - Demonstrate with details the principle characteristics of STATCOM using computer simulations such as Matlab/Simulink or PSCAD.
  - Propose and describe a suitable SCADA system for the project.
- **Relate the technical specifications of all the proposed features to the appropriate standards.**

Task 4: Distribution System (10 marks)

- Continue designing the distribution and utilization system to provide electricity to the town. Take into consideration the following:
  - Town load of 300 MW (industrial, commercial, and residential).
  - Specifications of the distribution substation including number and type of transformers; configurations; neutral grounding, etc.
  - The proposed topologies of distribution system for various types of loads: high- and low-density areas.
  - Protection system for transformers, feeders and laterals with technical specifications.
  - Capacitor banks: Read Example 14.3.
  - Specifications of utilization transformers.
  - Your design ends up with three typical loads: residential, commercial, and industrial. Show the sizing of required transformers.

Task 5: Wind Farm (10 marks)

- Conduct a feasibility study for initiating a profitable wind energy farm in Ontario. You may add electricity storage to your project to benefit from the peak premium! Generally the development and operation of a wind farm can be initiated with the following two steps:

- **Initiation and Feasibility (concluded by go/no-go)**
  - Municipal consultation.
  - Site selection and wind assessment (proposed site; available wind resource; wind power forecasting)
  - **Technical feasibility:** Description of candidate turbines.
- **Prebuilding (concluded by go/no-go)**
  - Wind farm design including energy yield predictions (wake losses; grid losses; availability)
  - Grid connection
  - Selection of suppliers.

Task 6: Lab Task (20 marks)

- In this lab, our objective is to study the potential impact of integration of distributed generation (wind farm) using the PowerWorld Simulator software.
- We simulate a very large capacity plant (a nuclear plant consisting of four reactors producing 750 MW each). Because these reactors are large, they will provide some voltage regulation by supplying or consuming MVARs.
- The nuclear plant serves a large city via two parallel transmission circuits, as well as the town at the mid-line of one of these lines. To simplify this lab, we model the large city as an infinite bus, which consumes any excess power generated by the plant.
- We may explore various phenomena resulting from distributed generation systems like wind farms, including the effects on power transfer and power system stability.
- This lab exercise provides insight on two very important issues in power systems, notably, the addition of distributed generation and the challenges involved with electrifying remote communities.

Final: Design Portfolio (20 marks)

- Submit a 10-page portfolio covering the five parts of grid development on the day of the final exam.
- A digital copy should be sent by email to the instructor on the same day.
- Include in your portfolio a general block diagram that shows the integration of transmission and distribution power systems, transmission and distribution control centers, energy service providers, communication links, possible distributed resources (wind), and typical types of customers.
- Clearly show the details of your design work.
- Include tables of component sizing.
- Include a summary of your lab work.