SENR 654 Smart Power Grids **Name (Print):** _____
Fall 2017
Midterm Exam 1
23-OCT-2017
Time Limit: 90 Minutes Signature _____

This exam contains 10 pages (including this cover page) and 5 problems. Check to see if any pages are missing. Enter all requested information on the top of this page, and put your initials on the top of every page, in case the pages become separated.

You may **NOT** use your books, notes, computers, smart phones, PDAs, tablets, or any computing devices on this exam.

You are required to show your work on each problem on this exam. The following rules apply:

- Students shall not communicate with one another in any manner whatsoever during the examination. Students may not leave the examination room unescorted for any reason, and this includes using the washroom/toilet/restrooms.
- **Organize your work**, in a reasonably neat and coherent way, in the space provided. Work scattered all over the page without a clear ordering will receive very little credit.
- **Mysterious or unsupported answers will not receive full credit**. A correct answer, unsupported by calculations, explanation, or algebraic work will receive no credit; an incorrect answer supported by substantially correct calculations and explanations might still receive partial credit.
- If you need more space, use the back of the pages; clearly indicate when you have done this.

Problem	Points	Score
1	13	
2	14	
3	16	
4	30	
5	27	
Total:	100	

Do not write in the table to the right.

1. State whether the following statement is **TRUE** or **FALSE**.
   (a) (1 point) Electrical energy is a primary energy source that we use in our daily lives to maintain our well-being.
   (b) (1 point) The first power grid was built by Nikola Tesla in New York, and it was using AC power to distribute electricity.
   (c) (1 point) In the GCC region, the vast majority of electricity is generated from coal and hydropower plants.
   (d) (1 point) In power grid operations, the generation must meet demand instantaneously because the energy storage capacity is still limited.
   (e) (1 point) Over the last two decades, transmission lines are carrying more power per unit transmission infrastructure due to increasing power demand and decreasing transmission infrastructure investments.
   (f) (1 point) Smart grids mainly shift the system operations from centralized fashion to decentralized way, by moving the focus to customer side.
   (g) (1 point) Nuclear and coal power plants are typically used to serve the peak demand.
   (h) (1 point) Solving a unit commitment problem is typically more complex than solving an economic dispatch problem.
   (i) (1 point) The cost ($/kWh) to serve residential customers is generally lower than the industrial customers.
   (j) (1 point) An Electric vehicle can be considered as a smart load because the charging current can be adjusted according to grid conditions.
   (k) (1 point) Underground transmission cables are typically less expensive to build than the overhead transmission.
   (l) (1 point) HVDC transmission lines typically used for underwater transmission lines and interconnection power grids.
   (m) (1 point) Non-intrusive load monitoring can be used to extract appliance level load profiles from aggregated electricity consumption data.

2. Fill in the blanks.

   (a) (3 points) Sort the distribution system types based-on cost efficiency.

   A. _____

   B. _____

   C. _____

   (b) (3 points) List 3 utility customer classes.

   A. _____

   B. _____

   C. _____

   (c) (3 points) List 3 main drivers of smart grids.

   A. _____

   B. _____

   C. _____

   (d) (5 points) Briefly explain "duck curve". You may use a simple graph to explain it.

3. The following questions include load factor calculations.

   (a) (3 points) During the year 2014, the peak demand for domestic electricity consumption was 5180 MW in Qatar. Moreover, $22,215,842$ MWh of energy was consumed in domestic sector. What is the annual load factor?

   (b) (3 points) During the year 2014, the peak demand for *industrial* electricity consumption was 1648 MW in Qatar. Moreover, $11,568,215$ MWh of energy was consumed in industrial sector. What is the annual load factor?

   (c) (4 points) Which load factor is higher and why? What does it imply in terms of unit electricity cost?

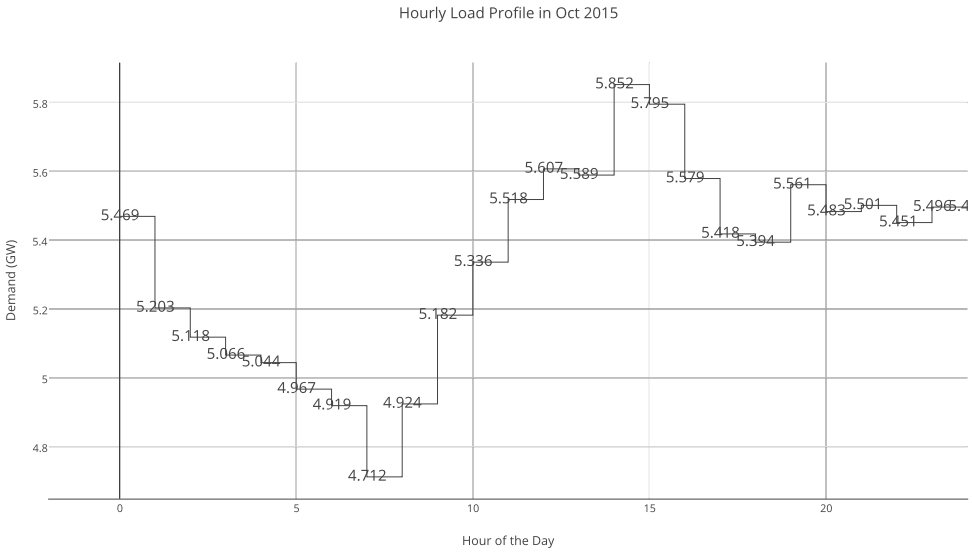
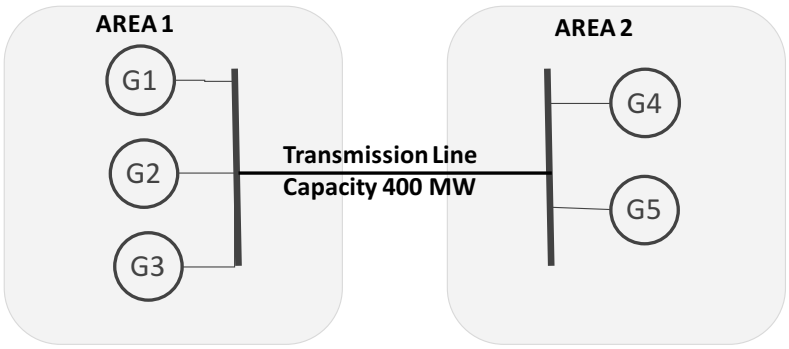


Figure 1: Hourly load profile in Qatar

(d) (6 points) Consider the load profile given in the Figure 1. What is the peak demand? What is the average demand? What is the total energy consumed? What is the Load Factor?



Generator	Output Capacity	Price $/ MWh
Generator 1	300 MW	$30
Generator 2	200 MW	$10
Generator 3	100 MW	$40
Generator 4	200 MW	$50
Generator 5	400 MW	$80

Figure 2: Energy auction example

4. Consider the power system given in Figure 2. Answer the following questions.
   (a) (15 points) Calculate the market clearing price when the load in Area 1 is 200 MW and the load in Area 2 is 400 MW. What is the output of each generator?

(b) (5 points) Which generators are dispatched in Area 1 and Area 2?

(c) (10 points) Suppose that the demand in Area 2 has increased to 900 MW. What is the market clearing price? What is the output of each generator?

Unit	P_{min} (MW)	P_{max} (MW)	Min up (h)	Min down (h)	No-load cost ($)	Marginal cost ($/MWh)	Start-up cost ($)	Initial status
A	150	250	3	3	0	10	1,000	ON
B	50	100	2	1	0	15	500	OFF
C	10	50	1	1	0	20	100	OFF

Figure 3: Cost components of three generators.

5. Consider the following unit commitment problem. Hourly demand for three time period are 150 MW, 300 MW, and 200 MW. There are three generations, namely A, B, and C, and their characteristics are given in the table above. The state of the generators are represented with binary numbers, 1 represent the generator is On and 0 represents the generator is Off. For instance, state 000 means all generators are Off, while state 111 represents all generators are On. The initial state of the generators are On, Off, and Off. The generators are going to serve three time periods for 150 MW, 300 MW, and 200 MW, respectively.

   (a) (3 points) Complete unit combinations table 1 shown below.

Table 1: Table for Question 5a

Combinations			Pmin	Pmax
A	B	C		
1	1	1	210	400
0	1	0	50	100

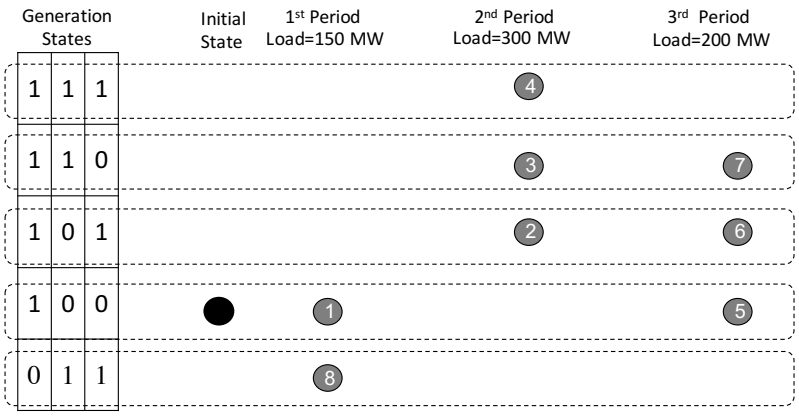


Figure 4: Unit committment problem Question 5b.

(b) (24 points) Consider the unit commitment problem given in Figure 4. The initial generator state is 100. For the given paths, if the path is feasible, then calculate the total cost. If the path is not feasible, write NOT FEASIBLE and explain. Show all your work to receive full credit. What is the cheapest path?

(c) Path: Initial state $\rightarrow 8 \rightarrow 2 \rightarrow 7$

(d) Path: Initial state $\rightarrow 8 \rightarrow 2 \rightarrow 6$

(e) Path: Initial state $\rightarrow 1 \rightarrow 2 \rightarrow 7$

(f) Path: Initial state $\rightarrow 1 \rightarrow 2 \rightarrow 6$

(g) Path: Initial state $\rightarrow 1 \rightarrow 2 \rightarrow 5$