EE101 TERM PROJECT 3

FOPS Wind Turbine Project

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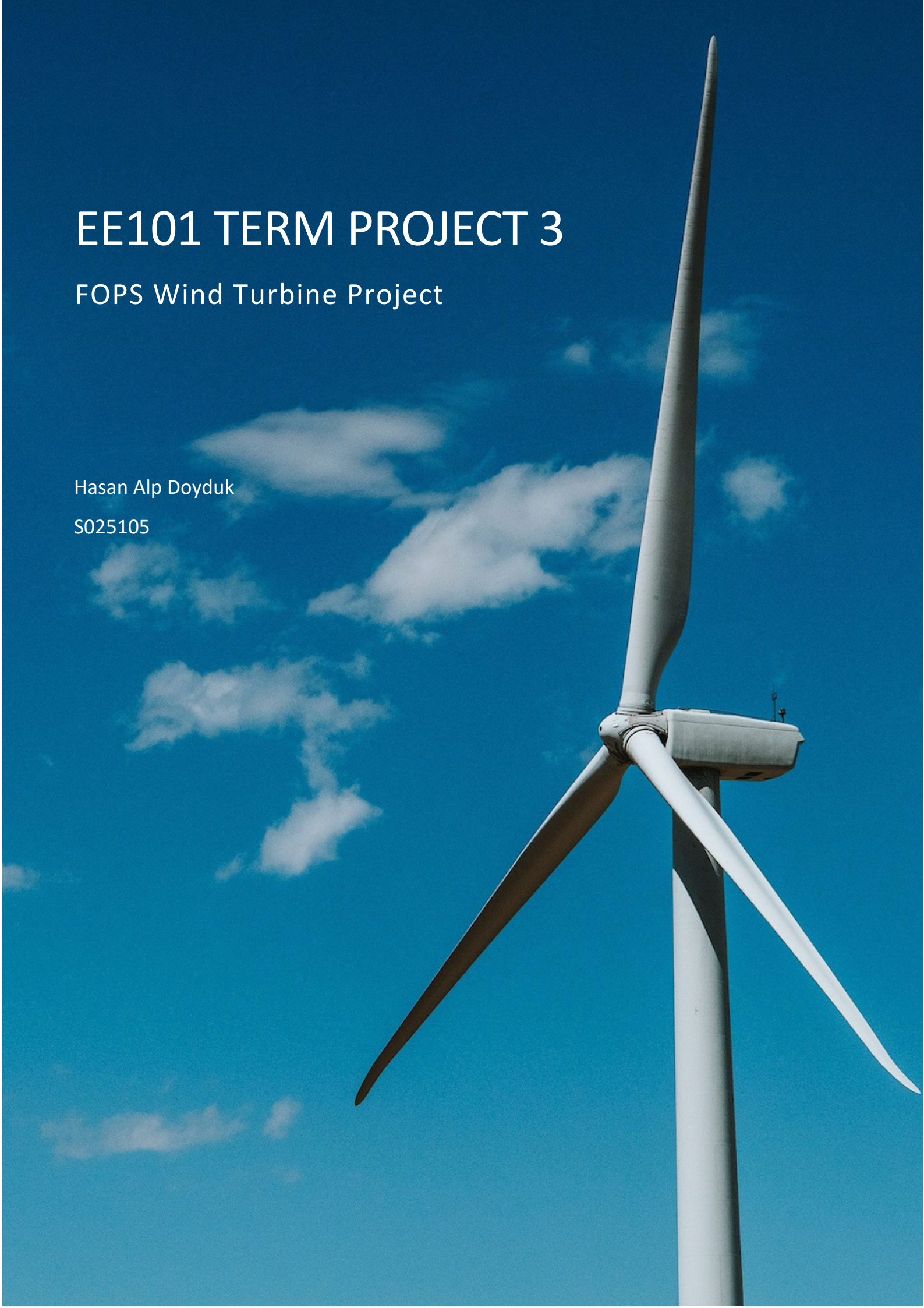
S025105



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Introduction of the Project

A 200 MW wind turbine will be built to the northwest of the Metropolis urban area. There are many different paths to transfer the electrical energy generated by this wind turbine to the city. As the FOPS company, our aim is to transmit the electrical energy produced by the wind turbine to the city with the least loss and to choose the least costly option during this process.

Current Situation

Currently, the system does not have a wind turbine. In this current case, there is a system loss of 10.71 MW. A 5-year plan was created with the current situation in order to compare with the 5-year plan after the wind turbine was built.

For the Current System Without Wind Turbine		
Number of hours in 5 years		43,800
Price for losses ($/MWh)	$	50.00
Power Losses (MW)		10.71
Energy Losses (MWh)		469,098
System Losses Cost ($)	$	23,454,900.00

Table 1. Calculation of the current system losses cost in a 5-year period

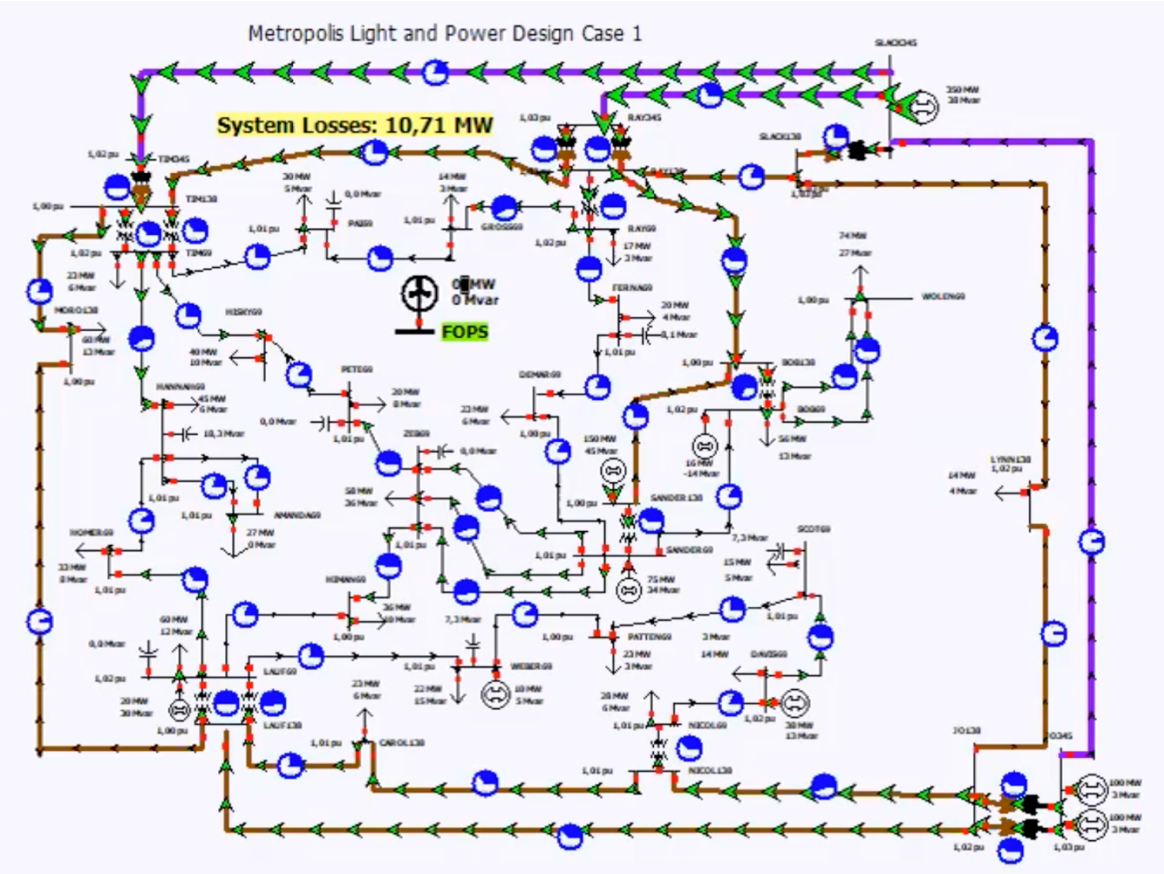


Table 2. Current situation of system in the PowerWorld simulation program

Transition to Case Studies

The wind turbine is worked by an equivalent conventional generator with an output of 200 MW, a voltage set point of 1.05 per unit and reactive power limits of ±100 MVAr. For reliability, two separate 69V supplies should be connected to the wind turbine from the stations. Moreover, the distances of the wind turbine to the stations are different, they are 20 miles to PAI, 25 miles to PETE and 30 miles to DEMAR.
Assuming that the system loss will remain constant for 5 years, the loss is calculated as $50/MWh. In addition, new transmission lines include a fixed cost and a variable cost. The fixed cost is $125,000 for a 69-kV line. The variable costs depend on the type of conductor and the length of the line. Also, conductors have different current rating, resistance, inductive reactance from each other.

Conductor Type	69-kV Lines
Rook	$200,000/mi
Crow	$220,000/mi
Condor	$240,000/mi

Table 3. The cost per conductor type

Conductor Type	Current Rating (Amps)	Resistance (ohms per conductor per mile)	Inductive reactance (ohms per conductor per mile)
Rook	770	0.1678	0.414
Crow	830	0.1472	0.407
Condor	900	0.1358	0.401

Table 4. Characteristics of conductors

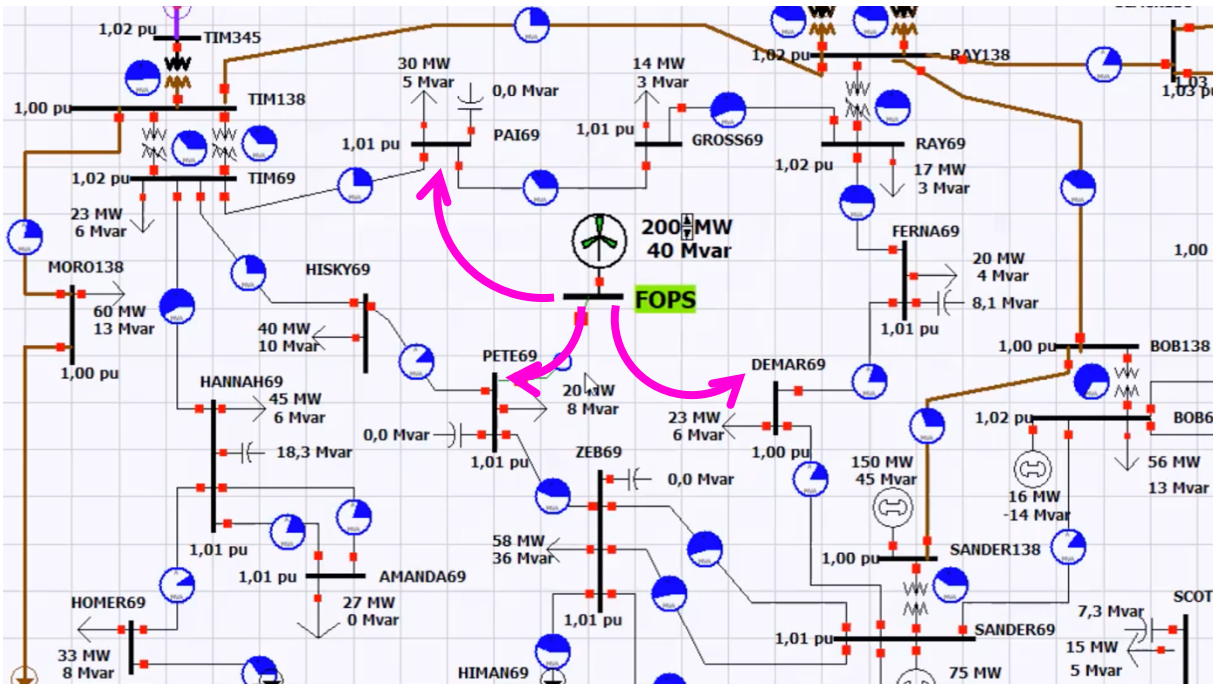


Table 5. Possible connection paths for wind turbine

Case Studies

27 situations where the wind turbine could be connected to Metropolis were simulated using PowerWorld. In these cases, station distances, cable types, system loss, cost due to system loss, cost of constructed transmission lines and total cost were calculated. These data are shown in the Table-6 and Table-7 with the PAI-PETE line in green, the PAI-DEMAR line in blue and PETE-DEMAR line in orange.
Successful cases were selected considering the overload caused by these cases in the cables and these are shown in yellow in the Table-6 and Table-7. The low system loss was also taken into account in the selection of successful cases.

Case Number	Station-1	Station-2	FOPS to Station-1 Conductor Type	FOPS to Station-2 Conductor Type	FOPS to Station-1 Distance (miles)	FOPS to Station-2 Distance (miles)
Case-1	Pai	Pete	rook	rook	20	25
Case-2	Pai	Pete	crow	crow	20	25
Case-3	Pai	Pete	condor	condor	20	25
Case-4	Pai	Pete	rook	crow	20	25
Case-5	Pai	Pete	rook	condor	20	25
Case-6	Pai	Pete	crow	rook	20	25
Case-7	Pai	Pete	crow	condor	20	25
Case-8	Pai	Pete	condor	rook	20	25
Case-9	Pai	Pete	condor	crow	20	25
Case-10	Pai	Demar	rook	rook	20	30
Case-11	Pai	Demar	crow	crow	20	30
Case-12	Pai	Demar	condor	condor	20	30
Case-13	Pai	Demar	rook	crow	20	30
Case-14	Pai	Demar	rook	condor	20	30
Case-15	Pai	Demar	crow	rook	20	30
Case-16	Pai	Demar	crow	condor	20	30
Case-17	Pai	Demar	condor	rook	20	30
Case-18	Pai	Demar	condor	crow	20	30
Case-19	Pete	Demar	rook	rook	25	30
Case-20	Pete	Demar	crow	crow	25	30
Case-21	Pete	Demar	condor	condor	25	30
Case-22	Pete	Demar	rook	crow	25	30
Case-23	Pete	Demar	rook	condor	25	30
Case-24	Pete	Demar	crow	rook	25	30
Case-25	Pete	Demar	crow	condor	25	30
Case-26	Pete	Demar	condor	rook	25	30
Case-27	Pete	Demar	condor	crow	25	30

Table 6. The fundamental data of the cases are shown, which are station names, station distances and cable types, additionally two successful cases are indicated in yellow.

System Losses (MW)	System Losses Cost	Line Cost	Total Cost of Case
23.07	$ 50,523,300.00	$ 9,000,000.00	$ 59,773,300.00
21.15	$ 46,318,500.00	$ 9,900,000.00	$ 56,468,500.00
20.11	$ 44,040,900.00	$ 10,800,000.00	$ 55,090,900.00
22.04	$ 48,267,600.00	$ 9,500,000.00	$ 58,017,600.00
21.46	$ 46,997,400.00	$ 10,000,000.00	$ 57,247,400.00
22.13	$ 48,464,700.00	$ 9,400,000.00	$ 58,114,700.00
20.59	$ 45,092,100.00	$ 10,400,000.00	$ 55,742,100.00
21.60	$ 47,304,000.00	$ 9,800,000.00	$ 57,354,000.00
20.65	$ 45,223,500.00	$ 10,300,000.00	$ 55,773,500.00
26.14	$ 57,246,600.00	$ 10,000,000.00	$ 67,496,600.00
24.08	$ 52,735,200.00	$ 11,000,000.00	$ 63,985,200.00
22.96	$ 50,282,400.00	$ 12,000,000.00	$ 62,532,400.00
25.28	$ 55,363,200.00	$ 10,600,000.00	$ 66,213,200.00
24.79	$ 54,290,100.00	$ 11,200,000.00	$ 65,740,100.00
24.90	$ 54,531,000.00	$ 10,400,000.00	$ 65,181,000.00
23.62	$ 51,727,800.00	$ 11,600,000.00	$ 63,577,800.00
24.20	$ 52,998,000.00	$ 10,800,000.00	$ 64,048,000.00
23.41	$ 51,267,900.00	$ 11,400,000.00	$ 62,917,900.00
27.64	$ 60,531,600.00	$ 11,000,000.00	$ 71,781,600.00
25.31	$ 55,428,900.00	$ 12,100,000.00	$ 67,778,900.00
24.03	$ 52,625,700.00	$ 13,200,000.00	$ 66,075,700.00
26.18	$ 57,334,200.00	$ 11,600,000.00	$ 69,184,200.00
25.34	$ 55,494,600.00	$ 12,200,000.00	$ 67,944,600.00
26.72	$ 58,516,800.00	$ 11,500,000.00	$ 70,266,800.00
24.51	$ 53,676,900.00	$ 12,700,000.00	$ 66,626,900.00
26.19	$ 57,356,100.00	$ 12,000,000.00	$ 69,606,100.00
24.81	$ 54,333,900.00	$ 12,600,000.00	$ 67,183,900.00

Table 7. The data of system losses and the economic data of the cases are shown, which are system losses cost, line cost and total cost of case, additionally two successful cases are indicated in yellow.

Fixed line cost not mentioned in Table-6 and Table-7 which is 125,000$ and it is an amount to be paid only for the construction of the transmission lines.

System losses and total costs of successful cases in the table are compared with the current situation data. There is a detailed analysis of these comparison on page 5.

The data in these tables were obtained using PowerWorld simulation program.

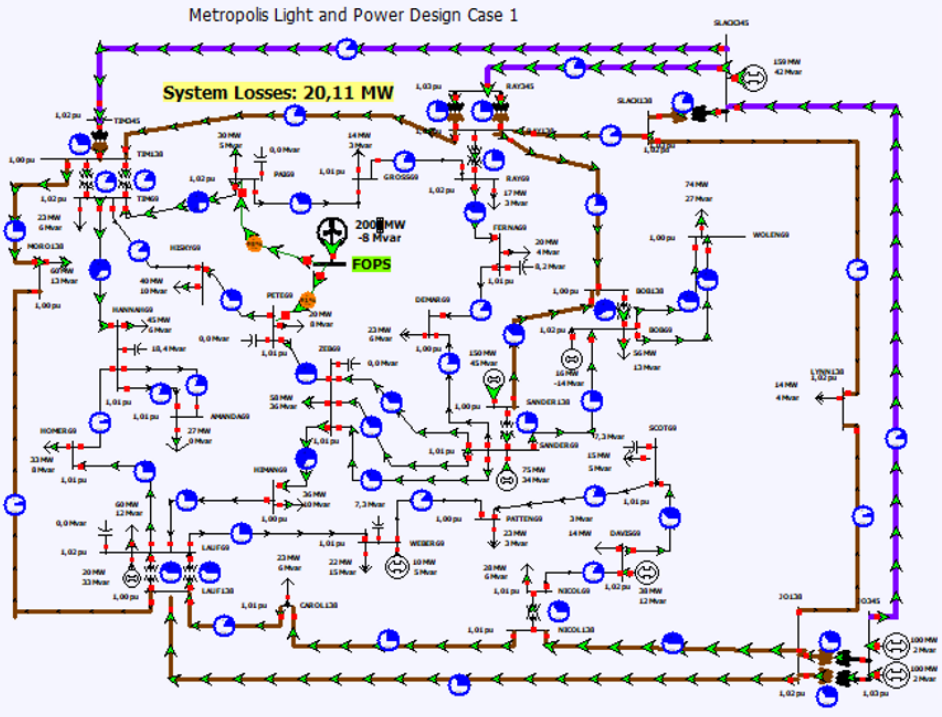
Specific Case Studies

Case-3

In this case, transmission lines were constructed from FOPS to PAI and from FOPS to PETE. These lines are one of the shortest lines between all cases which is 20 miles to PAI and 25 miles to PETE for this reason, it is one of the cases where the conductor cost and the cost due to resistance and inductive reactance is the least.
Even though the conductor price per mile is maximized by using the most expensive conductor which is named “Condor”, the resistance and inductive reactance cost per mile is minimized. In this way, system loss is reduced. Case-3 has the lowest system losses among other cases.
The most significant difference that distinguishes this situation from other situations is that the overload on the constructed transmission lines is less than the other lines which are FOPS to PAI 95%, FOPS to PETE 91%.

Case-3		
Number of hours in 5 years		43,800
Price for losses ($/MWh)	$	50.00
Power Losses (MW)		20.11
Energy Losses (MWh)		880,818
System Losses Cost ($)	$	44,040,900.00
Line Cost ($)	$	10,800,000.00
Fixed Cost ($)	$	250,000.00
Total Cost of Case ($)	$	55,090,900.00

Table 8. Calculating the system losses cost of Case-3 in a 5-year period



Transmission lines and the stations which are connected to the wind turbine are seen in the case model created using the PowerWorld simulation program. As seen in the simulation image, the conductors did not exceed the limit current they can carry. In other words, transmission lines are not overloaded, so this case became one of the successful cases.

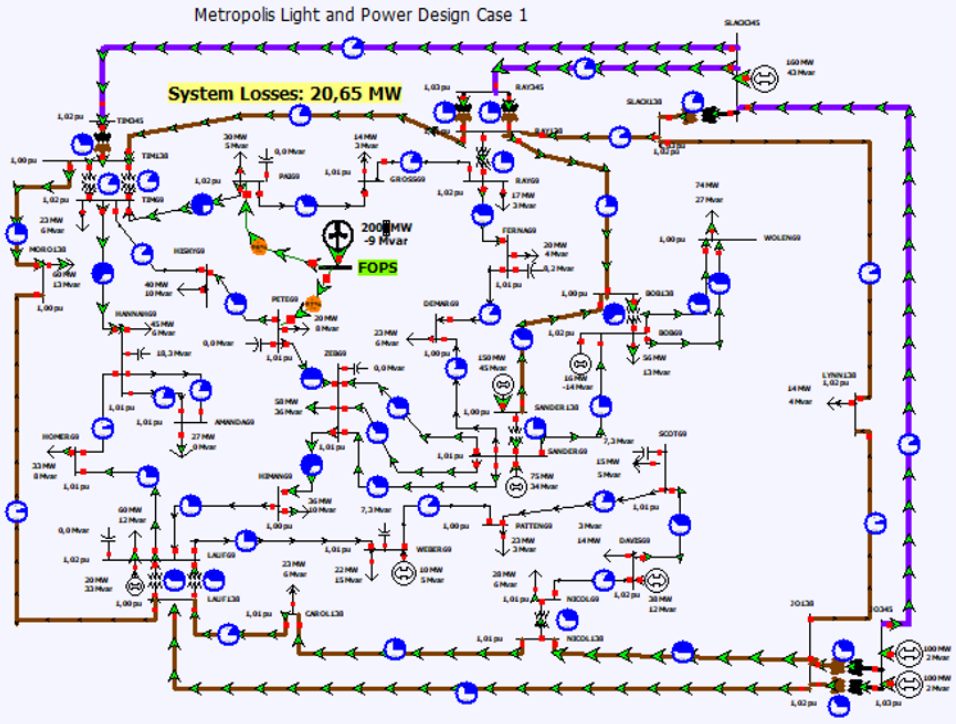
Table 9. The view of Case-3 in PowerWorld simulation program

Case-9

In this case, transmission lines were constructed from FOPS to PAI and from FOPS to PETE which is similar with Case-3.
FOPS to PAI “Condor” conductor, FOPS to PETE “Crow” conductor was used. In this way, the case has the second lowest system losses.
The most significant difference that distinguishes this situation from other situations is that the overload on the constructed transmission lines is less than the other lines which are FOPS to PAI 96%, FOPS to PETE 77%.

Case-9		
Number of hours in 5 years		43,800
Price for losses ($/MWh)	$	50.00
Power Losses (MW)		20.65
Energy Losses (MWh)		904,470
System Losses Cost ($)	$	45,223,500.00
Line Cost ($)	$	10,300,000.00
Fixed Cost ($)	$	250,000.00
Total Cost of Case ($)	$	55,773,500.00

Table 10. Calculating the system losses cost of Case-9 in a 5-year period



Transmission lines and the stations which are connected to the wind turbine are seen in the case model created using the PowerWorld simulation program. As seen in the simulation image, the conductors did not exceed the limit current they can carry. In other words, transmission lines are not overloaded, so this case became one of the successful cases.

Table 11. The view of Case-9 in PowerWorld simulation program

Case-3 and Case-9 are one the closest cases to the current situation in terms of the total cost. Case-3 costs 31,636,000$ and Case-9 costs 32,318,600$ more than current scenario.

Conclusion

As a result of the case studies on the wind turbine to be connected to the city of Metropolis, it has been concluded that there are two suitable cases (Case-3, Case-9) to be built in terms of system losses and total cost of case. When these cases are compared among themselves, it has been decided that Case-3 is a more efficient situation in terms of system losses and total cost of case.
As demonstrated in the most efficient example, Case-3, it would be most appropriate form for FOPS to build the wind turbine in the city of Metropolis.