cheapest total planning cost solution, i.e. by paying load shedding costs of 16.416 MW on bus 4. The optimal overall cost was $100.47 Million consisting of $13,783 million in transmission line investment costs, $89,397 million for electricity generation and load shedding costs.

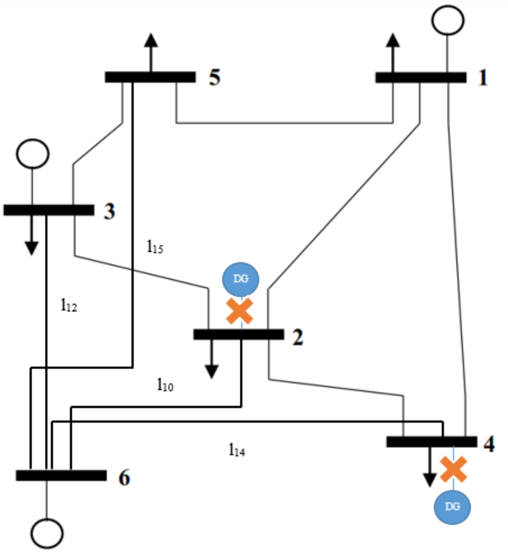

Fig. 5 Simulation results of 6-Bus system with TEP model with DG using load shedding costs.

TABLE VI
ALTERED LOAD SHEDDING COSTS VALUES

No.	Load	C_d^{LS} 1 ($/MWh)	C_d^{LS} 2 ($/MWh)	C_d^{LS} 3 ($/MWh)	C_d^{LS} 4 ($/MWh)	C_d^{LS} 5 ($/MWh)
1.	d_1	70	90	95	100	140
2.	d_2	71	110	115	120	142
3.	d_3	75	130	135	140	150
4.	d_4	85	140	145	150	170
5.	d_5	85	140	145	150	170

TABLE VII
LOAD SHEDDING COST COMPONENT SENSITIVITY ANALYSIS RESULTS

No.	Scenario	Total Planning Costs
1.	C_d^{LS} 1	$100.47 Million
2.	C_d^{LS} 2	$102.96 million
3.	C_d^{LS} 3	$103.18 million
4.	C_d^{LS} 4	$103.18 million
5.	C_d^{LS} 5	$103.18 million

D. Sensitivity of TEP Simulation Analysis with DP Implementation with Load Shedding Costs Component

Because the load shedding cost was still an assumption, then the sensitivity analysis of load shedding cost component influence was administered by administering running for 5 times on the designed program with load shedding costs data that was altered in accordance with the Table VI.

Those load shedding costs values then were put into the model, the results are as follows. Load shedding costs components would affect overall planning costs when the load shedding costs in the scenario were under C_d^{LS} 3, then for the values above C_d^{LS} 3, the model would not choose to pay the load shedding. Therefore, scenario with the most optimal result was by building DG on bus 4 with overall planning costs of $ 103.18 million. These results can be seen in Table VII.

V. CONCLUSION

In transmission line addition planning, the 6-Bus Graver system test required 5 additional lines, and this model's optimal value yielded total planning costs of $ 106.4 millions.

The result of transmission line addition planning with Distributed Generation without load shedding, in the 6-Bus Graver system test, using DG Combustion Turbine (CT) and Diesel Engine (DE) showed that the model would prefer to build DE type DE and build 4 new transmission lines, with a total planning cost of $103.18 millions.

Load shedding costs component will make total planning costs becomes cheaper if the load shedding costs at the average 5 loads are below $122/MWh.

Further research will focus on the DG impact towards the system's reliability. DG's impact and load uncertainty can also be added to the model.

REFERENCES

[1] G.A. Bakirtzis, P.N. Biskas, and V. Chatziathanasiou, “Generation Expansion Planning by MILP Considering Mid-Term Scheduling Decisions,” *Electric Power Systems Research*, Vol. 86, pp. 98–112. 2012.

[2] H. Park, and R. Baldick, “Stochastic Generation Capacity Expansion Planning Reducing Greenhouse Gas Emissions,” *IEEE Transactions on Power Systems*, Vol. 30, No. 2, pp. 1026–1034, 2015.

[3] C. Munoz, E. Sauma, J. Contreras, J. Aguado, and S. De La Torre, “Impact of High Wind Power Penetration Network Expansion Planning,” *IET Generation, Transmission Distribution*, Vol. 6, No. 12, pp. 1281-1291, 2012.

[4] K.S. Rao, M.N. Rao, “Multiple Distributed Generator Allocation by Harmony Search Algorithm for Loss Reduction,” *2012 International Conference on Emerging Trends in Electrical Engineering and Energy Management (ICETEEEM)*, 2012, pp. 59-64.

[5] M.H. Sulaiman, “Optimal Allocation and Sizing of Distributed Generation in Distribution System via Firefly Algorithm,” *2012 IEEE International Power Engineering and Optimization Conference (PEOCO2012)*, 2012, pp. 84-89.