Available Transfer Capability (ATC) enhancement using Distributed Generation

Arati Jaiswal

Electrical Engineering Department, University College Of Engineering and Technology, JNTU Hyderabad India

ABSTRACT

The efficient power transfer in a power system depends on accurately determining Available Transfer Capability (ATC) within system limits. As electricity demand increases, transmission lines become stressed, leading to congestion and reduced efficiency. To solve this, proper ATC evaluation is crucial for planning and operation. Using Flexible AC Transmission Systems (FACTS) can improve ATC, but they come with design challenges related to cost and complexity. This paper proposes an easier alternative—using Distributed Generation (DG) to enhance ATC

Keywords: Available Transfer Capability, Congestion, Distribution Generation.

I. INTRODUCTION

Power system restructuring refers to the transformation of the electric power industry to improve efficiency, reliability, sustainability, and competitiveness. This process involves changes in ownership, market structure, and regulatory frameworks across generation, transmission, distribution, and retail sectors.

A key concept in this context is Available Transfer Capability (ATC), refers to the amount of electric power that can be transferred over a transmission network from one area or region to another, while maintaining the reliability of the power system under normal and contingency conditions. It shows how much power can be safely transferred without overloading the system or causing instability. Congestion occurs when power flow exceeds a transmission line's capacity, leading to overloads, instability, and reduced efficiency. To maintain or enhance ATC under congestion, operators use the methods: Re-dispacting, Transmission upgrades, Facts Devices, Demand Response, Power Flow Controllers. Integrating distribution generation (DG), especially from renewables like solar and wind, helps improve ATC, enhance grid stability, and reduce congestion [1]. DG optimizes power flow and increases ATC, particularly during peak demand or congestion periods [2]. Combining congestion control with market mechanisms can effectively boost ATC and support reliable power trading [3]. An 11-bus model in a deregulated setup shows that proper loss handling improves market efficiency [4]. Power World Simulator is used to analyze how DG integration improves ATC, manages congestion, and optimizes flow in restructured grids [5].

II. DISTIBUTION GENERATION(DG)

Distributed Generation (DG) refers to small-scale power sources like solar panels and CHP units located close to the load. Integration of DG to Enhance Available Transfer Capability (ATC). Locating DG near load centers reduces power losses and frees up capacity on transmission lines, increasing ATC. DG helps relieve transmission congestion by generating power locally, reducing stress on overloaded lines.

DG, especially synchronous generators, can supply reactive power, improving voltage profiles and system stability. DG integrated with smart grids and FACTS devices enables better control of power flow, enhancing system flexibility and ATC.

III. ATC CALCULATION

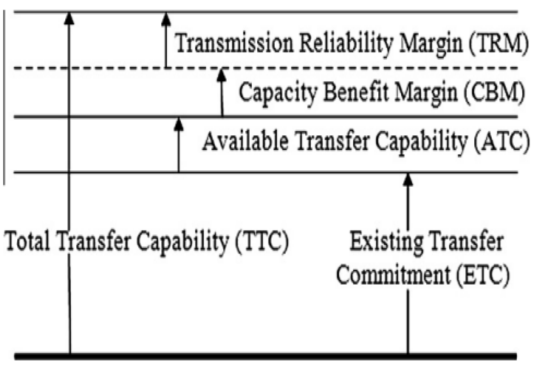


Fig.1 ATC for Normal case

ATC is calculated using the following steps:

Total Transfer Capability (TTC)
TTC represents the maximum transferable power without violating operational limits.

Transmission Reliability Margin (TRM)
TRM accounts for uncertainties like load variation, generation loss, or outages.

Existing Transmission Usage (ETU)
ETU includes current power flows and scheduled transfers already using the network.

ATC Formula:

$$ATC = TTC - ETU - TRM$$

Scenario-Based Evaluation
ATC should be assessed under various conditions:

Base Case: Normal operations

Contingencies: Outage scenarios

Peak Load: Seasonal high-demand conditions

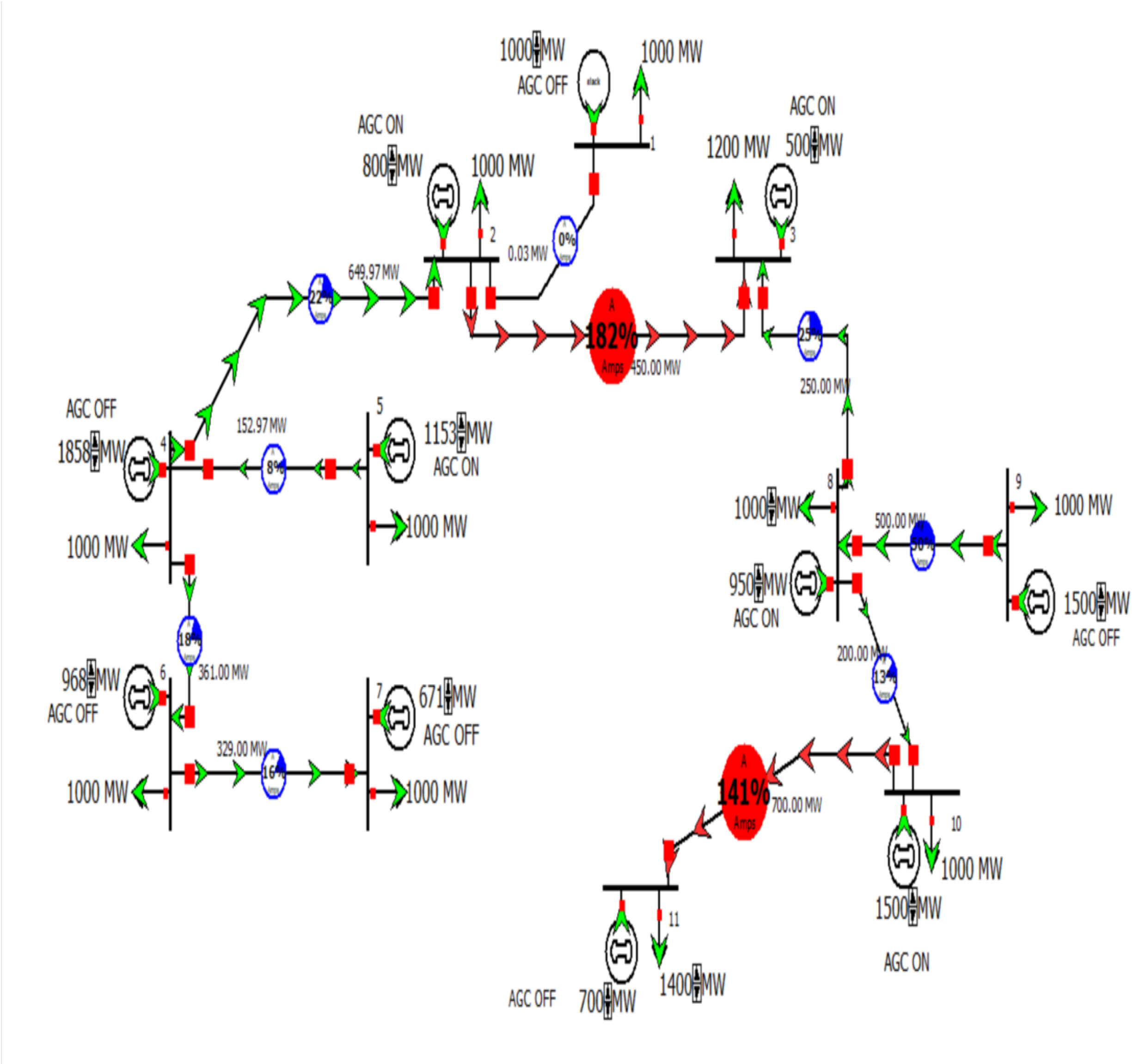
1. Impact of Distributed Generation (DG)
   DG, by supplying local loads, reduces transmission loading and enhances ATC. It is modelled in simulation tools by adjusting generation patterns.
2. Simulation Tools
   Tools like Power World Simulator and PSS/E are used for power flow studies, TTC calculation, and scenario analysis.

IV. SIMULATION AND RESULTS

Case Study:
To gain insights into available transfer capability with distribution generation and without distribution generation, consider and explore IEEE 11 bus system through simulation using power world simulator, followed the analysis and results.
The provided diadram (figure 2) showcases a 11 bus system. In the

simulation, significant congestion is observed due to a heavy 1200 MW load at bus 3. This overload causes limitations on the transmission lines between buses 2–3 and 10–11, restricting efficient power flow. The results highlight the negative impact of congestion on system performance and reliability. We can see the max capacity of generation is 1000MW for all the generation. And load at bus3 is 1200 MW and bus11 is1400 MW other loads are same 1000 MW.

Fig.2 ATC without DG Simulation Model

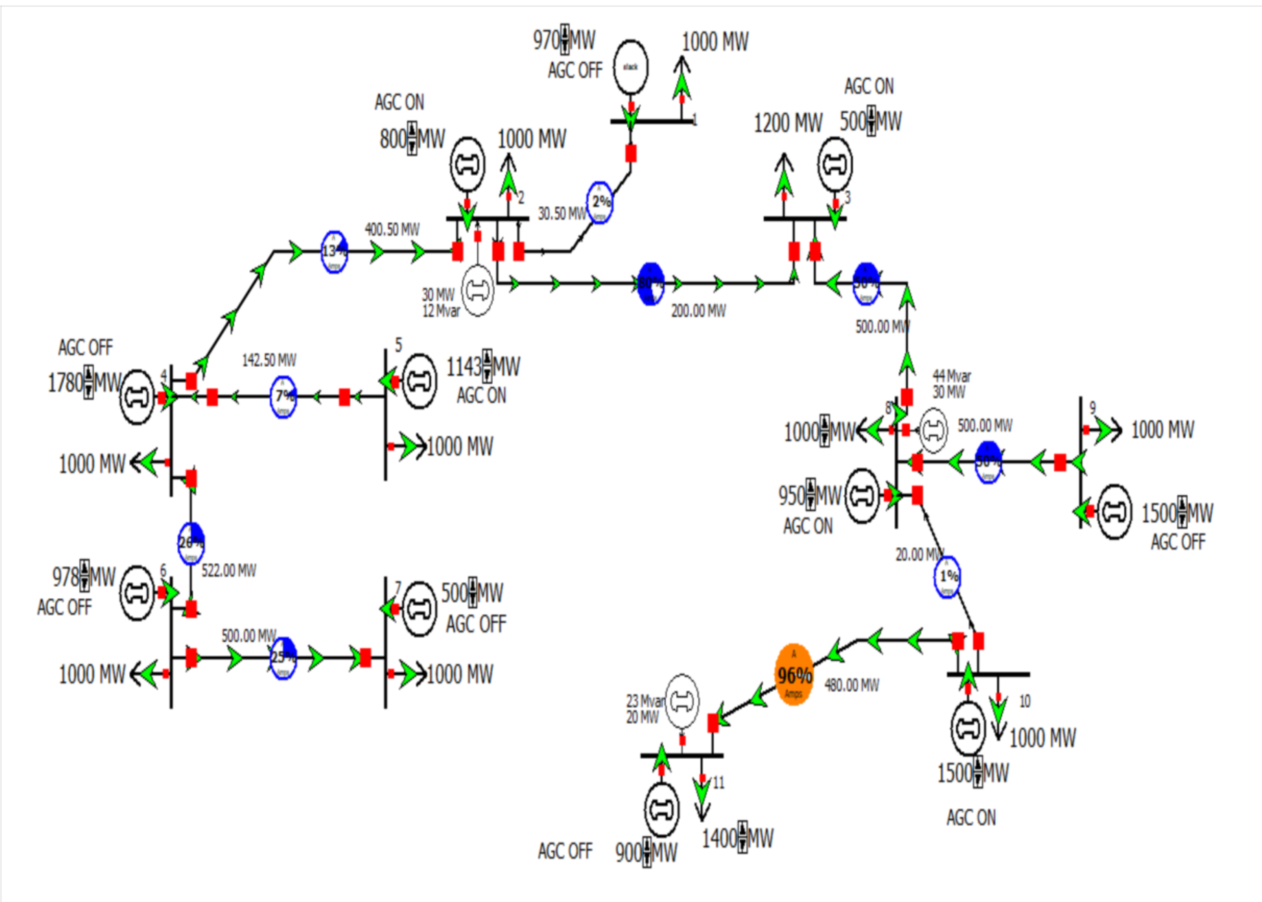


In this first simulation (figure2) it is showed that congestion are occur in 2 buses. In one bus congestion are 182% which can cause big problem to transmission line. One congestion occur between bus 10 and bus 11 which is indicated in red color with 141% it means power are exceed by 41 % and it is not in limit. For this reason congestion management is required.

Location of Distributed Generation

Distributed Generation (DG) should be placed near high-demand areas and congestion points in the transmission system. In this study, DG was added at bus 2 to reduce congestion caused by a 1200 MW load at bus 3. Similarly, DG units were installed at buses 11 and 14 to address congestion near a 1400 MW load at bus 11.

Fig.3 ATC with DG Simulation Model



In second simulation (figure3) we can see congestion are removed by using distribution generation. Limit are in control by using 3 distribution generation on different bus, bus 2, bus 8, bus 11. And limit of transmission line also got increased which will help to enhance ATC.

After installing DG, congestion dropped significantly—from 182% to 80% and from 141% to 96% in various scenarios (Figure 3). Placing DG near load centers helps supply power locally, reduces stress on transmission lines, and improves system efficiency and reliability, especially during peak demand.

Table.1 Available Transfer Capability value without DG

Applied step size at bus 3 load (Mw)	Load to bus	Bus to bus	Power flow (MW)	ATC (MW)	Maximum limit (MW)
10	1210	2 to 3	453.39	546.61	1000
20	1220	2 to 3	456.73	543.27	1000
30	1230	2 to 3	460.06	539.74	1000
40	1240	2 to 3	463.39	536.61	1000
50	1250	2 to 3	466.73	533.27	1000
60	1260	2 to 3	470.63	529.37	1000
70	1270	2 to 3	473.39	526.07	1000
80	1280	2 to 3	476.73	523.27	1000
90	1290	2 to 3	480.06	519.94	1000

Simulation Steps

1. In the initial scenario, key system parameters such as bus voltages, angles, generator outputs, load data, and power flows are determined

2. A change in active power at Bus 3 is introduced, and a power flow analysis is conducted using Power World Simulator.

3. Power Transfer Distribution Factor (PTDF) and Available Transfer Capability (ATC) values are calculated for each transaction.

4. Transmission Capability (TC) for individual transactions is computed, followed by the overall ATC calculation for the entire network.

5. The first ATC is determined without distributed generation (DG), considering the increased load at Bus 3.

6. A second simulation is performed with DG added at Bus 2, Bus 8, and Bus 11.

7. ATC is recalculated with the inclusion of DG.

8. A comparison between Table 1 (without DG) and Table 2 (with DG) shows an increase in ATC values after DG integration.

Table.2 Available Transfer Capability values with DG

Applied step size at bus 3 load (Mw)	Load to bus	Bus to bus	Power flow (MW)	ATC (MW)	Maximum limit (MW)
10	1210	2 to 3	204.04	795.16	1000
20	1220	2 to 3	208.4	791.94	1000
30	1230	2 to 3	212.26	787.7	1000
40	1240	2 to 3	216.06	783.94	1000
50	1250	2 to 3	220.60	779.4	1000
60	1260	2 to 3	224.06	775.01	1000
70	1270	2 to 3	228.06	771.94	1000
80	1280	2 to 3	232.06	767.94	1000
90	1290	2 to 3	236.06	763.94	1000

Using the data in Table 1 we gradually increased the load at bus 3 by 10 MW and monitored the power flow between bus 2 and bus 3**.** The variation in ATC values with increased loading is illustrated in Fig. 3. Without DG, the ATC decreases quickly as load increases, indicating limited capacity.

Same for Table 2 we gradually increased the load at bus 3 by 10 MW and monitored the power flow between bus 2 and bus 3**.** The variation in ATC values with increased loading is illustrated in Fig. 4. With DG, the ATC remains higher even at increased load levels.

Fig. 2, the simulation of Available Transfer Capability (ATC) without Distributed Generation shows congestion, particularly in the transmission line from bus 2 to bus 3. This indicates that the system cannot handle additional load without exceeding line limits, creating a bottleneck in power flow.

After integrating DG, as shown in Fig. 3**,** the simulation reveals a significant improvement. The congestion in the transmission line is eliminated, and power flows efficiently. This demonstrates how local generation reduces the burden on transmission lines by supplying power closer to the load.

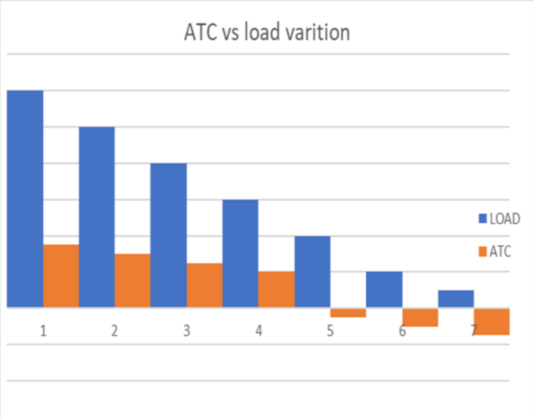


Fig.4 ATC vs Load variation

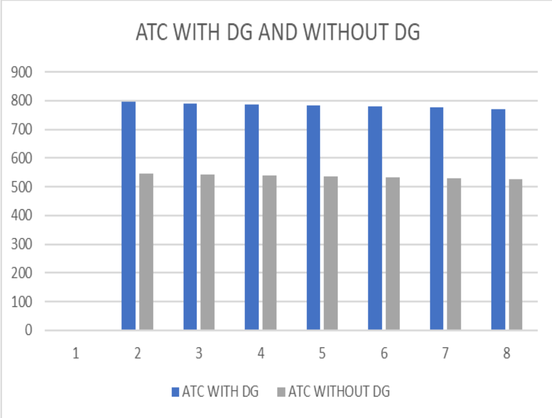


Fig.5 ATC without DG vs ATC with DG

Fig. 5 shows a direct comparison of ATC with and without DG. The results clearly show that the presence of DG improves ATC. By generating power locally, DG reduces line loading and improves overall system flexibility.

So adding Distributed Generation helps increase ATC, remove transmission congestion, and ensure more secure and reliable power delivery. This supports the idea that integrating DG is a practical solution for enhancing grid performance, especially under growing load conditions

V. CONCLUSION

This study demonstrated that Distributed Generation (DG) effectively improves Available Transfer Capability (ATC) in power systems. DG enhances grid stability, reduces transmission losses, and supports local demand, particularly during peak periods. Simulation results, especially Figure 5, confirmed increased ATC with DG, notably under load variations at Bus 3. DG also helped ease congestion and improved transmission efficiency. Overall, DG is a key approach for enhancing ATC and preparing power systems for future needs.

REFERENCE

1.Zhao, H., & Liu, Z. (2016). "Impact of Distributed Generation on Power System Transfer Capability." *IEEE Transactions on Power Systems*, 31(3), 2101-2110.

2. Javadian, S., & Niayesh, S. (2018). "Improving Available Transfer Capability using Microgrids and Distributed Generation." *Energy Systems*, 9(4), 627-644.

3. Guan, X., & Li, Z. (2016). Integrated Congestion Management and Market Clearing for Enhancing ATC. *IEEE Transactions on Power Systems*, 31(4), 3170-3178.

4.R.D. Christie; B.F. Wollenberg; I. Wangensteen "Transmission management in the deregulated environment" Proceedings of the IEEE Volume: 88, Issue: 2, February 2000.

5. Khare, V., & Soni, S. (2018). Enhancing Available Transfer Capability Using

Distributed Generation: A PowerWorld Simulation Approach. *Journal of Electrical Engineering & Technology*, 13(1), 321-328.

6. P.W. Sauer "Technical challenges of computing available transfer capability (ATC) in electric power systems" : Proceedings of the Thirtieth Hawaii International Conference on System Sciences 07-10 January 1997.

7. S. C. SRIVASTAVA "Available Transfer Capability (ATC) Determination in a Competitive Electricity Market Using AC Distribution Factors" September 2004Electric Power Components and Systems 32(9):927-939.

8. Aishvarya Narain1 · S. K. Srivastava1 · S. N. Singh "A novel sensitive based approach to ATC enhancement in wind power integrated transmission system".