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A Comprehensive Approach to Site Renewable Generation Based on Maximum Generation Profit

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SUMMARY

As more and more large renewable generation projects are proposed to interconnect to the power grid, the renewable generation developers face challenges on where to site the renewable generation projects. This article proposes a comprehensive methodology to screen out the most profitable site among several candidate sites. The methodology has two steps: Power injection capacity analysis and Pro Forma analysis.

Power injection capacity analysis is to identify the maximum transmission system injection capacity without causing adverse impact on the transmission system. The adverse impact associated with the renewable generation project can be thermal overload, voltage violation and etc. For each candidate site, the generation project should be sized no larger than the maximum transmission system injection capacity, and this can avoid the high cost of any major transmission system upgrade. The maximum injection capacity is achieved through load flow contingency analysis.

Pro Forma analysis is to assess the long term financial performance for each of the renewable generation sites. The Pro Forma analysis is based on the locational marginal price forecast(LMP) from multi-area production simulation. The LMP forecast combined with the generation output forecast can estimate the revenue and profit of the renewable generation project. By comparing the Pro Forma for each candidate site, we can identify the site with maximum generation profit.

This article includes an example of screening 3 candidate sites in ERCOT by contingency analysis and multi-area production simulation. Several sensitivity analyses are addressed for implementing the methodology.

KEYWORDS

Production Simulation, Load Flow Analysis, Transmission Planning, Generation Interconnection, Renewable Generation Siting.

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1. BACKGROUND

As more and more large renewable generation projects are proposed to interconnect to the power grid, the renewable generation developers face challenges on where to site the renewable generation projects. For high generation profit, the good renewable generation site candidate need have sufficient onsite renewable resources, enough transmission system power injection capacity, and high locational marginal prices (LMP). In most of the cases, the renewable resources are located far away from the load center, in the other words, the renewable generation requires transmission system power injection capacity in order to provide power to the grid and serve the load. In this article, we proposed a practical methodology to assist developers to screen out the site that has maximum generation profit among all the candidate sites, and evaluate the renewable generation project on long term financial performance. The site selection of the new generation project is based on both the transmission reliability criteria and the power market operation.

2. METHODOLOGY

We assume that all the candidate generation sites have sufficient renewable resources (land, wind/solar resource), and we focus only on the transmission system maximum power injection capacity and Pro Forma analysis on the renewable site selection.

The maximum power injection capacity is the largest renewable generation injection at the candidate site without causing adverse impact on the transmission system. The adverse impact associated with the renewable generation project can be thermal overload, voltage violation and etc. For each candidate site, the generation project should be sized no larger than the maximum power injection capacity, and this can avoid the high cost of any major transmission system upgrade. In order to calculate the transmission system power injection capacity, power flow analysis is conducted. The power flow analysis includes normal or contingency conditions.

The Pro Forma analysis is based on LMP results from production cost simulation/ power market simulation.

2.1 Power Injection Capacity Analysis

The flow diagram to identify the maximum injection capacity is shown in Figure 1. For each candidate site, an initial injection MW is estimated, and the initial estimate could be very small so that there is no violation for the first iteration on the contingency analysis. The injection MW can be increased ΔMW for each iteration, and the ΔMW can vary according to different transmission systems. If the thermal or voltage violation is identified in iteration step i, the maximum injection capacity is the MW applied in iteration step i-1.

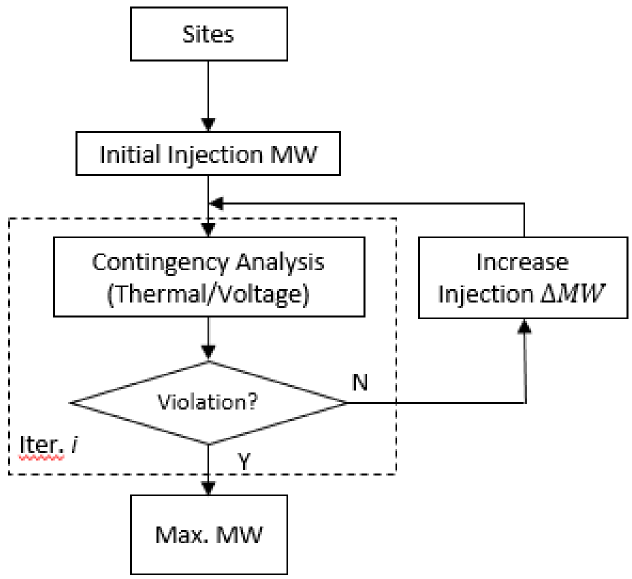

Figure 1: Steps to Identify the Maximum Injection Capacity

Once the maximum transmission system injection capacity is identified for each candidate site, the maximum injection capacity is applied to the power market simulation model to estimate the Pro Forma for each candidate site.

2.2 Pro Forma Analysis

The Pro Forma analysis is based on LMP results from multi-area production cost simulation/ power market simulation. The major advantage of a multi-area production cost simulation is to simulate the least-cost operation of a power system while ensuring the system's security constraints are not violated. These security constraints include the operating limits and capabilities of generation sources, constraints and contingencies imposed by the transmission system and the operational limits such as minimum operating reserve levels.

Figure 2 illustrates the way to calculate the site plant Pro Forma by production cost simulation. The production cost simulation engine has inputs, and these inputs include the assumptions on energy & demand forecast, fuel forecast (gas, coal and oil), generator characteristics (heat rate, emission and etc.) and other market operation rules. There is a benchmark process to tune the model so that the results align to the expectation.

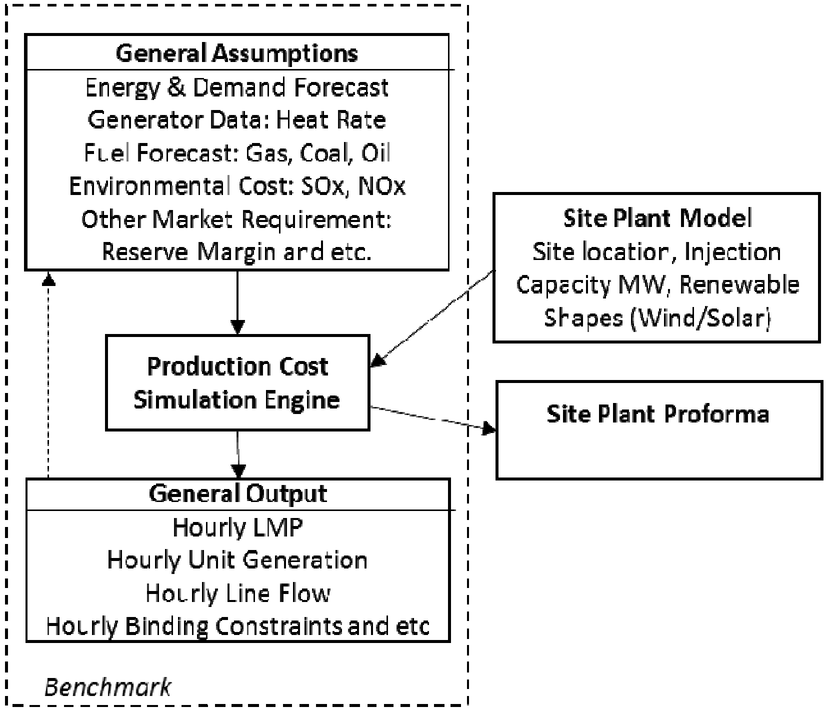

Figure 2: Site Plant Pro Forma Calculation

We use GE Multi-Area Production Simulation (GE MAPS) software for a transmission constrained, multi-area production simulation.

3. EXAMPLE

We choose three candidate solar sites to assess, and these three sites are in Electric Reliability Council of Texas ("ERCOT") region. The locations of these three candidate sites are shown in Figure 3.

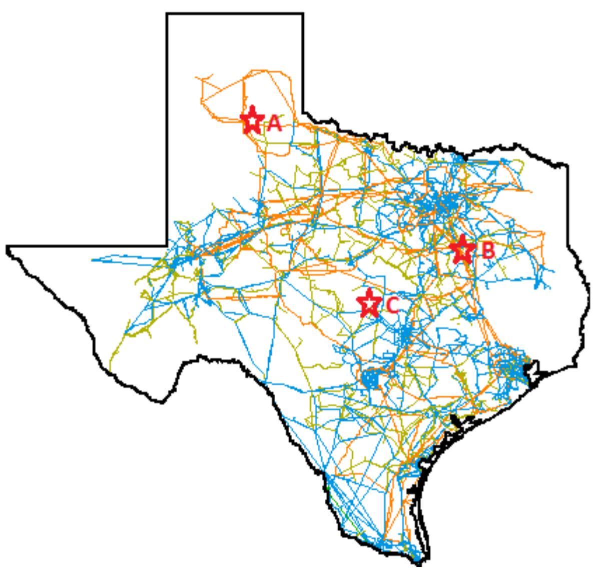

Figure 3: Candidate Sites

3.1 Power Injection Capacity Analysis

The power injection capacity analysis is to identify the maximum injection capacity per the procedure of the connecting transmission system operator. The power injection capacity analysis is conducted through load flow contingency analysis. For ERCOT, the contingency list includes: single contingency and multiple facility contingency (double circuit tower line contingency, line with failed breaker and bus fault and etc.). The corresponding voltage rating and thermal rating are applied in the load flow contingency analysis.

For the load flow contingency analysis, prior interconnection queue projects need special attention. The prior interconnection queue projects may have a significant impact on the estimate of the maximum injection capacity and Pro Forma performance of the proposed renewable project. This is especially the case for the area that has significant more available renewable resources when compared to other nearby areas, and the developers don't have other areas as the option since the limitation of the available renewable resources. Different prior queue projects must compete the limited available transmission capacity. Because the developer usually has some insights on the competitor in the region, the developer can specify certain scenarios on projects to be included in the study.

For Site A, it is in Texas panhandle area, which has heavy wind renewable resources. After modelling the prior queue projects (mostly wind projects) in the panhandle area, because of the panhandle transmission transfer limit, it is found that the there is no available power injection capacity.

Similar load flow contingency analysis approach is applied to Site B and Site C. The results are summarized in Table 1 below.

Table 1: Maximum Injection Capacity

Site	**Maximum Injection Capacity (MW)**
A	0
B	150
C	200

3.2 Pro Forma Analysis

Based on the power injection capacity analysis, the maximum injection capacity of the transmission system is identified. If there is enough land and solar/wind resource available to produce the maximum injection, the generation capacity(MW) is then identified for each candidate site. Otherwise, the generation capacity will be calculated based on the renewable resource available. These maximum generation capacities can be applied to the Pro Forma analysis.

Besides the generation capacity(MW), hourly renewable generation outputs need to be estimated based on the renewable resource data. We collect the available local historical wind or solar data, then this renewable historical data is converted to generation MW per the corresponding renewable technology. Except that there are several renewable generations competing a congested transmission path on certain hours, these renewable generation are usually dispatched and are delivered to serve the load through the transmission system because of the usually low cost of the renewable generation.

With both the capacity MW and the hourly output MW for each candidate site, the production simulation is then conducted. Table 2 summarizes the Pro Forma output for Site B and Site C.

Table 2: Site Pro Forma

	Site B	Site C
Average Capacity (MW)	150	200
Energy Revenue ($1000)	$190,499	$242,842
Total Variable Costs ($1000)	$0	$0
Energy Margin ($1000)	$190,499	$242,842
Energy Margin (%)	100%	100%
Total Gross Margin ($1000)	$190,499	$242,842
Gross Margin ($/kW-yr)	1270	1214
Fixed O&M ($1000)	$42,347	$56,463
EBITDA ($1000)	$148,152	$186,379
EBITDA Margin (%)	78%	77%
Less: Capitalized Maintenance (k$)	$10,587	$14,116
Cash Available for Distribution (k$)	$137,565	$172,263

From the Pro Forma summary, we can see that Site B has slightly better EBITDA margin than Site C. Overall, among the three candidate sites, Site B and Site C have better sites based on maximizing the profitability.

3.3 Other Sensitivity Analysis

In addition to the main two steps, there are special sensitivity analysis can be used to quantitate the potential impact of certain assumption variations. These assumption variations include: fuel/gas price forecast, local potential transmission upgrade and Power Purchase Agreement (PPA) assessment.

Fuel/gas price forecast has a significant impact on the performance of the renewable generation project. Additional gas forecasts, such as higher and lower than the expected gas price, can be applied to the production cost simulation as a sensitivity analysis.

For the power injection capacity analysis, there may be local uncertain future transmission upgrade project in the planning level. In this sensitivity analysis, this uncertain transmission upgrade can be added to load flow model to measure the impact on the proposed renewable project's injection capacity.

Lots of renewable generation projects have opportunities to sign PPA with potential investors. To assess the long-term market risk of a PPA, the production cost simulation can model multiple forward-looking sensitivities for each PPA opportunity.

4. CONCLUSIONS

This article proposes a comprehensive methodology to choose the renewable generation project site based on maximizing generation profit. The methodology has two steps: power injection capacity analysis and Pro Forma analysis. The approach takes into account of both the transmission planning reliability criteria and the power market operation.

5. FURTHER WORK

The study does not consider the option of the transmission system upgrade to increase the maximum injection capacity. The future work may include both the upgrade cost estimate and the pro forma simulation results, and evaluate the siting of the project. Besides the steady state contingency analysis, there are other aspects limiting the maximum injection capacity, other detailed analysis should be conducted on a specific system according to the transmission system characterises.

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