Assessing the Realism of Synthetic Power Grid Models Using Real-World Case Studies in Ghana

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***Abstract*—Developing realistic synthetic electric grid models for specific geographic regions is an important topic of power systems research. Synthetic grids provide researchers with testbeds for studying region-specific problems and informing associated policies. This paper presents two validation studies for one such synthetic grid model developed for Ghana, a West African country. First, we conduct a reliability study of the country's electric grid to identify the most critical lines. Next, we solve a Transmission Network Expansion Planning (TNEP) problem to identify the minimum-cost set of transmission lines to be constructed to satisfy a forecasted loading scenario. The results of these two studies contribute to validating the realism of the synthetic grid model. The most critical lines identified in our reliability analysis align with those for which faults have previously caused major blackout incidents. Furthermore, the lines identified by the TNEP solution are spatially aligned with a subset of actual transmission expansion projects proposed by the Ghana Grid Company. Ultimately, the similarity between the validation test results and real-world observations helps to validate the realism of the synthetic grid and demonstrates its usefulness in advancing power system research in Ghana.**

***Index Terms*—Synthetic Electric Grids, Reliability, Cascading Failures, Transmission Network Expansion Planning.**

I. INTRODUCTION

By facilitating algorithmic benchmarking and techno-economic studies, synthetic electrical grids are valuable tools for advancing power systems research and development. When created with authentic geographic information, synthetic grids can be further used to address region-specific problems and inform corresponding policies. Since synthetic grids are created using publicly available information, they enable research insights without revealing critical energy infrastructure information (CEII) [1] or other sensitive data. Multiple repositories exist for synthetic grid models across many regions in the United States and Europe [2], [3], but to date, there has been little focus on non-Western countries.

In our prior work [4], we developed a first-of-its-kind synthetic Ghanaian electric grid model, for a country in Africa, intended for steady-state studies in the region. We created this test case by combining information from multiple publicly accessible sources across the internet, utility company reports, and methods from the literature to resemble the National Interconnected Transmission System (NITS) of Ghana. This test case is intended to serve as a tool for developing algorithms to address problems specific to that country. In this paper, we consider two such applications, specifically, a grid reliability assessment and a transmission network expansion planning study, to validate the realism and utility of this synthetic grid.

This paper focuses on validating the accuracy and usefulness of this synthetic grid via two experiments. In our first validation experiment, we conduct a reliability assessment of the Ghanaian electric grid using the open-source MATLAB-based platform `Cascades` [5], [6]. This study identifies the lines in Ghana's transmission network that are most critical to the stable supply of electricity; outages on these lines could cause significant blackouts. We evaluate the realism of the synthetic grid by comparing these lines with outage data from the Ghana Grid Company (GRIDCo), the Electricity Company of Ghana (ECG), the Northern Electricity Distribution Company (NEDCo), and other relevant sources. While GRIDCo is the sole power transmission company, ECG and NEDCo are the power distributors to the customers, with ECG managing the southern and central corridors and NEDCo distributing power in the northern parts of Ghana.

Our second experiment utilizes the synthetic grid in a Transmission Network Expansion Planning (TNEP) analysis. We consider a future loading scenario in which the total national load matches the projected value from the GRIDCo. We identify the critical, most cost-effective transmission investments needed to meet this projected load increase. After determining the new lines to be added to the network, we analyze and compare the results with GRIDCo's planned projects, as provided in [7], to identify similarities as a second metric for evaluating the realism of the synthetic grid models.

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To summarize, this paper presents a novel approach to validating the realism of international synthetic electric grids. Although substantial work has been done in synthetic grid research, to the best of our knowledge, none of it uses real-world scenarios to validate model accuracy in the manner presented in this paper. By using the TNEP results and identifying the critical lines, we provide a *unique* way to confirm the fidelity of the synthetic electric grid model. This approach of using blackout data and transmission grid expansion plans to validate realism is most effective in developing regions like Ghana, where blackouts are common and data on faulted lines are publicly available, further emphasizing the value of these validation methods for synthetic grids in a global context.

The remainder of the paper is organized as follows. Section II describes the latest version of our synthetic grid model for Ghana. Sections III and IV formulate the reliability study and TNEP, respectively. Section V summarizes our results, and Section VI gives a detailed analysis and discussion. Section VII concludes the paper.

II. SYNTHETIC GRID MODEL UPDATES

Building on our prior work [4], we developed an updated version of the Ghanaian synthetic grid model based on recently published field reports, utility company statements, etc. A 2022 tariff proposal document submitted by GRIDCo to the Public Utilities Regulatory Commission (PURC) in Ghana outlines the most recent infrastructure upgrades to the national grid [7]. This document provides a list of completed transmission lines and substation projects from 2019 to 2022. None of these are included in the ECOWAS dataset [8] used to create the synthetic grid model in [4]. We updated our synthetic grid model with these new features to more accurately reflect the Ghanaian transmission network.

More specifically, new substations have been constructed at `Adubuliyili` (330 kV), `Nayagnia` (330 kV), `A4BSP` (330 kV), `Kasoa` (161 kV), `Dunkwa` Substation (330 kV), `K3BSP` (330 kV), `Karpower` (330 kV), `A4BSP` (161 kV), and `Nkawkaw` (330 kV). Additionally, eight new transmission lines were added to connect these recently commissioned substations to the existing transmission network.

Finally, we include shunts on selected buses to make the model AC-feasible. We do this using an optimal shunt placement problem that minimizes the total number of shunts added to the network [9]. The most updated version (version 3) of the model is publicly available in the MATPOWER [10] format.[1] In this latest version, we also provide the geographical coordinates (longitude and latitude) of all buses. Table I summarizes the technical composition of the updated model.

TABLE I
TECHNICAL SUMMARY OF THE SYNTHETIC GHANA GRID MODEL

Component	Buses	Branches	Generators	Transformers
Count	107	168	24	20

III. GRID RELIABILITY ASSESSMENT

This section describes the `Cascades` platform and outlines the steps in the associated reliability study of the synthetic Ghana system.

A. Overview of `Cascades`

`Cascades` is a tool for risk and vulnerability simulations and transmission expansion planning [5], [6]. This tool integrates probabilistic risk assessment with deterministic power flow solvers to simulate outage propagation. `Cascades` operates via the principle of Cascading Failure Simulations (CFS), with at least a yearly load-demand profile.

B. Cascading Failure Simulations

The CFS model simulates the evolution of cascading failures in a power system following initial contingencies. The engine evaluates the system state at each discrete stage of a cascade, accounting for thermal overloads, protection system actions, and emergency control measures. The model implements both single- and multi-zone CFS [11]. We adopt a single-zone analysis, as Ghana operates with a single Transmission System Operator (TSO), GRIDCo. The entire CFS pipeline is characterized by Figure 1.

The process begins with an initial system state where optimal generation is established, followed by the introduction of $N-k$ contingencies via Monte Carlo sampling. By simulating both single and multiple simultaneous failures, and by calculating Demand Not Served (DNS), the model identifies system risks[2] and generates risk curves using complementary cumulative distribution functions.

The simulation engine employs a multi-step recursive algorithm to maintain system stability during a cascade. Upon the formation of electrical islands, the model calculates steady-state frequency deviations (Δf) and initiates Under-Frequency Load Shedding (UFLS) to restore power balance. Subsequently, power flow calculations are performed to assess voltage stability and branch flows. If voltage thresholds are violated, a stepwise Under-Voltage Load Shedding (UVLS) procedure is triggered. The model further identifies thermal overloads, trips the most critical branches, and re-evaluates the topology until no further violations occur, thus capturing the blackout's evolution.

There are several outputs from the CFS simulation, but this paper focuses on a single criticality metric: the branch impact on DNS, BD_ℓ. This metric aggregates the total energy deficit attributed to specific branch failures across various loading conditions and contingency sets. Ranking the BD_ℓ values for all lines, $\mathcal{L}$, in the network identifies the most critical lines, whose failures could lead to load shedding or blackouts. Section V-A provides these numeric results for the synthetic Ghana system. Overall, the results of this study provide a detailed reliability assessment and identify lines requiring infrastructure upgrades and emergency control strategies.

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[1] The model data is available at https://doi.org/10.5281/zenodo.15148468.

[2] Risk = $\sum(\text{Probability}(i) \times \text{DNS}(i))$; where i is the event (contingency).

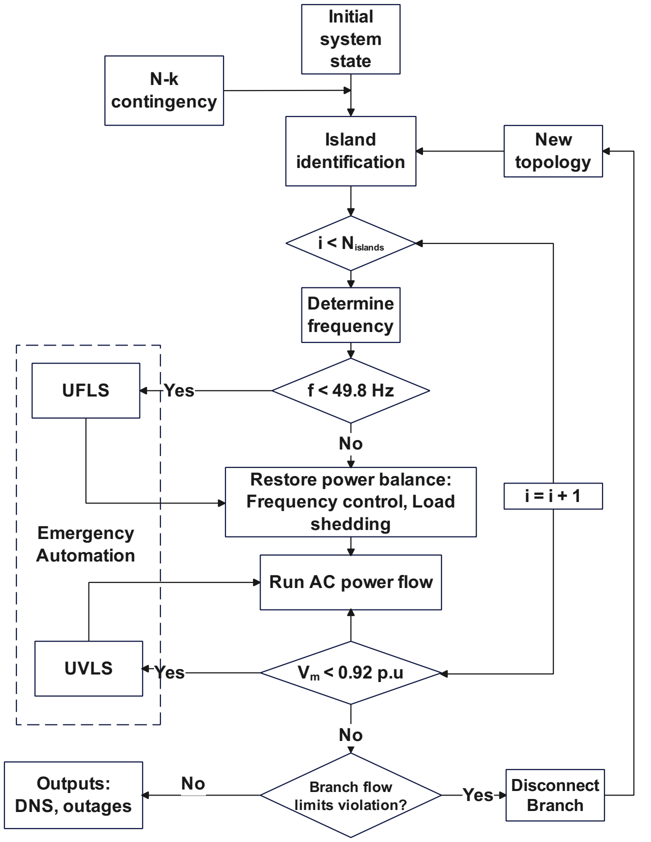

Fig. 1. A simplified flow-chart of the Cascading Failure Simulation (CFS) model [12].

C. Creating Load Demand Profiles

A critical requirement of the Cascading Failure Simulation is a representative yearly demand profile. This section describes how we create a high-resolution demand matrix, $D \in \mathbb{R}^{\mathcal{N} \times T}$, where $\mathcal{N} = 107$ and $T = 8,760$ denote the number of buses in the system and hours in a standard year, respectively. Since hourly data for each substation in the NITS is not publicly available, we develop a representative model[3] using publicly available data and estimation techniques.

We align our annual hourly demand profile by constraining both the monthly peaks and average monthly demand reported by the Ghana Energy Commission in [13] and generate the hourly values using a randomization logic. The method synthesizes hourly demand by modeling daily cycles as a superposition of three distinct load components: a dynamic base load, a morning rise, and a pronounced evening peak. The daily shape is governed by an adapted Gaussian-based bimodal distribution [14], [15] as specified in (1) below, where B represents the dynamic base load, while A_1 and A_2 denote the peak amplitudes for the morning and evening surges:

$$P_{daily}(t) = B + A_1 e^{-\frac{(t-\mu_1)^2}{2\sigma_1^2}} + A_2 e^{-\frac{(t-\mu_2)^2}{2\sigma_2^2}}. \qquad (1)$$

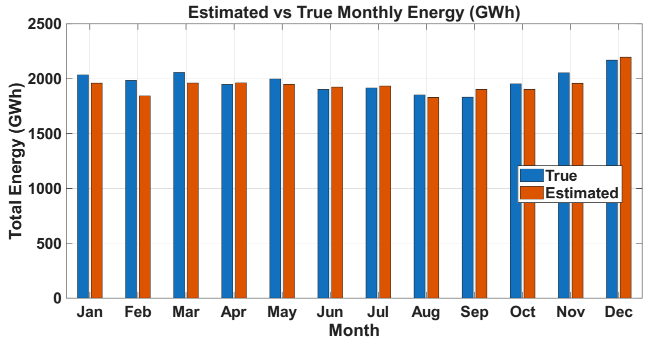

Fig. 2. A comparison of the monthly reported energy demand with the estimated demand for each month in 2024.

Based on historical load characteristics of the Ghanaian grid, A_1 is set to 0.12 to represent the moderate morning rise peaking at $\mu_1 =$ 08:00 hours, while A_2 is set to 0.40 to capture the more significant evening peak occurring at $\mu_2 =$ 20:00 hours. The standard deviations σ_1^2 and σ_2^2 control the temporal width of these peaks, with σ_2^2 being seasonally adjusted between 12 and 18 to ensure the total energy consumption aligns with the reported monthly GWh totals.

The method synthesizes hourly demands and allows us to time the monthly peaks to mimic stochastic grid stress. The estimated annual energy demand profile (23, 322.50 GWh) has a Mean Absolute Percentage Error (MAPE) of 2.86% from the actual demand of 23, 701.46 GWh [13]. The month-by-month comparison of the estimated and reported energy demand is shown in Fig. 2.

IV. TRANSMISSION NETWORK EXPANSION PLANNING

The second experiment used in our validation is a Transmission Network Expansion Planning (TNEP) problem conducted using the Ghanaian synthetic grid model. This TNEP problem seeks to identify the optimal set of new transmission lines to be constructed to meet Ghana's growing electricity demand.

A. Mathematical Formulation

We consider a transmission system with a set of generators, $\mathcal{G}$, and a set of buses, $\mathcal{N}$, each with a load, d. The set of existing transmission lines is denoted as $\mathcal{L}^{\text{ex}}$ and the set of candidate lines that can be added to the network is denoted as $\mathcal{L}^{\text{cand}}$. For the candidate lines $c \in \mathcal{L}^{\text{cand}}$, we introduce a binary variable, y_c, which is 1 if the line is built and 0 otherwise.

The TNEP problem minimizes the investment cost in transmission lines to ensure power delivery under a target load scenario. We assume that no new substations or generators

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[3] The loading profile is available at https://doi.org/10.5281/zenodo.20579370

are added. The TNEP problem is formulated as:

$$\min \sum_{c\in\mathcal{L}^{\text{cand}}} I_c\, y_c \tag{2a}$$

$$\text{s.t.} \sum_{g\in\mathcal{G}_i} p_g - d_i = \sum_{\ell\in\mathcal{L}^{\text{ex}}} f_\ell + \sum_{c\in\mathcal{L}^{\text{cand}}} f_c, \quad \forall i \in \mathcal{N} \tag{2b}$$

$$P_g^{\min} \le p_g \le P_g^{\max}, \quad \forall g \in \mathcal{G} \tag{2c}$$

$$-F_\ell \le f_\ell \le F_\ell, \quad \forall \ell \in \mathcal{L}^{\text{ex}} \tag{2d}$$

$$-F_c y_c \le f_c \le F_c y_c, \quad \forall c \in \mathcal{L}^{\text{cand}} \tag{2e}$$

$$f_\ell = B_\ell(\theta_i - \theta_j), \quad \forall \ell = (i,j) \in \mathcal{L}^{\text{ex}} \tag{2f}$$

$$f_c - B_c(\theta_i - \theta_j) \le M(1 - y_c), \quad \forall c \in \mathcal{L}^{\text{cand}} \tag{2g}$$

$$f_c - B_c(\theta_i - \theta_j) \ge -M(1 - y_c), \quad \forall c \in \mathcal{L}^{\text{cand}} \tag{2h}$$

The goal of this problem is to minimize the investment cost required to meet all future demand. For each candidate line, $c \in \mathcal{L}^{\text{cand}}$, a unique investment cost, I_c, is assigned to represent the total cost of building that line. This investment cost is a function of the line's length and the cost per mile to build it.

We model the constraints of this problem as a modification of the DC optimal power flow problem. Constraint (2b) represents the power balance equation at every bus, and (2c) bounds the output of each generator, $g \in \mathcal{G}$. Constraints (2d) and (2e) limit the flow on each existing line within the rated limits, F_ℓ. Candidate lines, $c \in \mathcal{L}^{\text{cand}}$, have their rated limits modified by the binary decision variable, y_c. If the line is built, y_c is 1, and the flow limits are defined by the transmission line ratings. Alternatively, if the line is not built, the flow in that line is 0. Finally, (2f), (2g), and (2h) implement the DC power flow approximation. The flow in each line is a function of the line susceptance, B, and the voltage angle, θ, of buses connected by the line. For the candidate lines, we implement this using the big-M linearization as shown in (2g) and (2h).

B. Candidate Lines

The candidate transmission lines are obtained via Delaunay triangulation, which is commonly used for estimating transmission network topology in synthetic grid research [16]–[18]. Our prior work in [19] shows that combining the network's minimum spanning tree with Delaunay triangulation provides a reasonable estimate for the topology of the Ghanaian transmission network. As possible additional lines, we treat all Delaunay lines as candidates in the TNEP problem, as shown in Figure 3. This yields a 151 candidate lines, with 31 at 330 kV and 120 at 161 kV. Note that, due to geographical constraints and right-of-way issues, many of the lines shown in the Delaunay triangulation may not be routed exactly as depicted in the figure or may be infeasible in practice.

C. Transmission Line Construction Cost Parameters

Several factors contribute to the total cost of any transmission project, including land acquisition, environmental studies, administrative costs, project management, and other related expenses. Beyond project management decisions, several technical considerations impact the total project cost, including conductor types, steel versus wood towers, and breaker types. For simplicity, we model the cost of adding new lines in a TNEP problem via the cost-per-km coefficient [20]–[22].

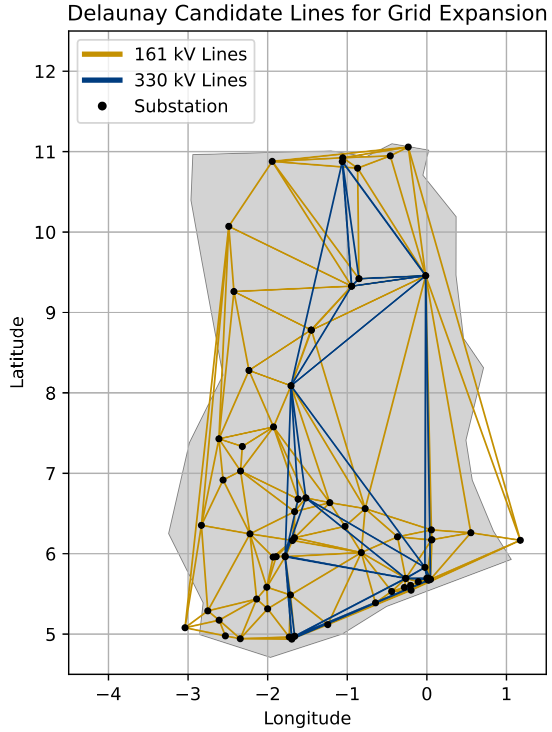

Fig. 3. Plot showing all candidate lines in the National Interconnected Transmission System of Ghana.

No known publicly available resource gives the details of expansion planning projects in Africa. Conversely, the Midcontinent Independent System Operator (MISO) in the United States provides available records of its estimated costs to build new transmission lines, expressed in US dollars per mile [23]. We use this data for our transmission cost modeling.

In the MISO models, the estimated cost of the new transmission lines depends on the voltage level and the state in which they are being built. For this paper, we compute the average across states for a given voltage level and use it in our TNEP problem. Consequently, the cost to build 1 km of 330 kV line is US\$3.56 million, and US\$1.83 million for 1 km of 161 kV line. The lengths of the transmission lines are the shortest paths between the substations' geographic coordinates.

We note that additional factors, such as volatile currency exchange rates and loan interest rates, may affect MISO's estimates. Further, capital and labor costs may differ significantly in Ghana, making them less directly applicable in this context. However, we still use the MISO estimates for this application as we lack more accurate information for the local context.

D. Loading Scenario under Projected Demand Growth

Since 2000, electricity demand in Ghana has tripled, prompting significant investments in transmission infrastructure to accommodate the increased load. In [7], GRIDCo provides information on the forecasted demand growth. GRIDCo projects total energy consumption increasing from $23,578.51$ GWh in 2022 to $34,920.18$ GWh in 2027 [7]. This represents an increase of $\approx 48\%$ over the five-year period.

To distribute the forecasted load growth across the country's buses, we use each area's population as a basis. Population has been shown to be a good indicator of load growth [24]. Therefore, we assign projected load growth proportional to each region's population. Under this new loading scenario, we perform the TNEP analysis, and the results for these simulations are provided in Section V-B.

V. Numerical Results

This section presents results for both the reliability study and the TNEP problem discussed in Sections III and IV.

A. *Results of Reliability Assessment*

This subsection presents the results of running the Cascading Failure Simulation model on the synthetic Ghanaian electric grid. For the evaluation of the CFS, a list of $1,000$ contingencies is used for each loading condition, and 18 loading conditions are selected from the yearly load curve, resulting in $18,000$ cascading failure simulations. The values above were obtained through a sensitivity analysis by [12] and considered sufficient for exploring the risk curve.

1) System Risk: Out of $18,000$ simulated events, $12,851$ (71.4%) resulted in a significant amount of Demand Not Served (i.e., blackouts). Almost all of these events were caused by a single contingency, i.e., only one device (line, transformer, etc.) experienced a fault. Further, no total system collapse was recorded in any of the event simulations, indicating that the grid remained at least partially operational throughout the simulation period. A system-wide summary is shown in Figure 4. The system recorded a total DNS of 11.14 GW and the highest possible DNS of 1.41 GW occurs at very low probability (< 0.001), further validating the absence of any system collapse during the simulation.

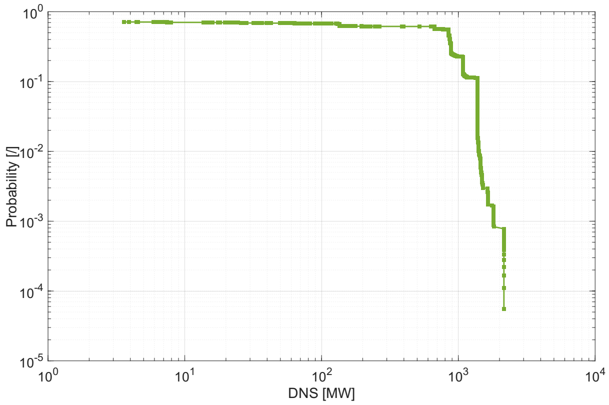

Fig. 4. Risk curve obtained from the `Cascades` reliability study highlighting the Demand Not Served and the probability of its occurrence.

2) Identification of Critical Components: The `Cascades` simulation identified the ten most critical components based on their impact on system-wide DNS, as shown in Table II. The two 161 kV transmission lines connecting `Akosombo` to `Tafo` are the most critical. Additionally, the corridor between `Nkawkaw` and `Tafo`, with a line rating of 161 kV, recorded the third-highest DNS. A substation modeled as a power transformer (161/69 kV) located in the community of `Asiekpe` was also flagged as having a high impact on DNS (10.22 MW). In the Western region, the line from `Prestea` to `Tarkwa`, both of which are heavily mining-affected areas, also recorded an aggregated impact of 9.45 MW.

Two transmission substations in the Northern region, one in `NewTamale` and the other in `Bolgatanga2`, were also identified. The former, modeled as a step-up transformer rated at $161/330$ kV, had an impact of 9.14 MW, and the latter, a step-down transformer rated at $330/225$ kV, had a slightly lower impact of 8.72 MW. The next two highest DNS lines were located in the Volta region. Both lines are 69 kV, one from the low-voltage end of the substation (i.e., step-down transformer) of `Asiekpe` linking it to `Ho` and the other from `Ho` to `Kpevee` with a DNS of 8.58 MW and 8.075 MW respectively. Finally, the line from `Bolgatanga2` to `NewTamale` had a DNS of 7.20 MW.

TABLE II
Top Ten Most Critical Transmission Lines

Type	Name	DNS (MW)	Previous Outage
Line	`Akosombo` to `Tafo`	46.69	[25]–[27]
Line	`Akosombo` to `Tafo`	39.99	[25]–[27]
Line	`Nkawkaw` to `Tafo`	29.00	[28] [29]
Transformer	`Asiekpe`	10.22	[30]–[34]
Line	`Prestea` to `Tarkwa`	9.45	[35], [36]
Transformer	`NewTamale`	9.14	[37]–[39]
Transformer	`Bolgatanga2`	8.72	[40], [41]
Line	`Asiekpe` to `Ho`	8.58	[33], [34], [42]–[45]
Line	`Ho` to `Kpevee`	8.08	[33], [34], [44], [45]
Line	`Bolga2` to `NewTamale`	7.20	[39], [40]

B. *Transmission Network Expansion Planning*

The optimization model (2) was implemented in Julia [46] using JuMP [47], and the resulting mixed-integer optimization problems were solved with Gurobi. Under the forecasted load scenario, total demand increased by 50.5% from $2,648$ MW to $3,986.3$ MW. Without installing new transmission lines, the existing network cannot meet the increased demand, further validating the need for the expansion planning model. There are multiple thermal limit violations in transmission lines in the Ashanti and Greater Accra regions. More specifically, lines connecting the `Nkawkaw`, `Tafo`, `Mallam`, `Achimota`, `Aboadze`, and `Takoradi` are all overloaded, preventing the solver from obtaining a feasible solution.

As summarized in Table III, the TNEP solution identifies four new lines that should be constructed with an estimated total cost of US\$275.98 million. As shown in Figure 5, these lines are located in the densely populated middle and southern parts of Ghana. Further discussions are provided on these lines in Section VI-B.

TABLE III

CHARACTERISTICS OF THE SELECTED TRANSMISSION LINES

Line	From Bus	To Bus	Length (km)	Cost ($M)
Line 1	`Dunkwa2`	`Obuasi`	23.82	43.59
Line 2	`Dunkwa2`	`ESAyanfuri`	12.48	22.84
Line 3	`Akwatia`	`NewAbirem`	42.61	77.98
Line 4	`Akwatia`	`Winneba`	71.90	131.57

VI. ANALYSIS AND DISCUSSIONS

To validate the synthetic Ghana grid model, this section first compares the critical lines identified in Section V-A with actual outage data for Ghana. The lines selected for construction by the TNEP problem in Section V-B are then compared to GRIDCo's actually proposed expansion plans.

A. Reliability Assessment Results

The reliability study described in Section III identifies the most critical transmission lines that, when outaged, would result in significant DNS. The results of performing this study on the synthetic Ghana grid are shown in Table II. To validate that these results based on the synthetic Ghana system are consistent with the behavior of the actual system, the table also provides links to news articles in which outages and planned maintenance on these critical lines have previously caused real-world blackouts.

In Ghana, long-period power outages are very common and have since gained a popular name, "Dumsor" — persistent and intermittent power supply interruptions [48], [49]. As a result, it is common for utilities and media outlets to report power outages caused by faults and utility-planned maintenance. This accounts for the large amounts of public data on outages in Ghana, hence enabling this method of synthetic grid validation.

To further reaffirm the reliability study results, we also investigated reports for several lines that were not identified as critical by the Cascades model. News articles indicated that these lines did not cause blackouts during planned maintenance and outages. As two examples, maintenance on the 161 kV `Akosombo–Nkawkaw` line was carried out without service disruption [50], [51], and reconstruction work on the `Achimota–Mallam` corridor was completed without affecting power delivery to GRIDCo customers [52]. These analyses confirm that a line outage does not directly translate into observable service disruptions and further corroborate the criticality of the lines identified by `Cascades`, which resulted in blackouts.

B. Transmission Planning Results

The TNEP solution in Section IV identifies four lines that should be built to meet the forecasted demand. These lines are located in the Ashanti and Eastern regions, which are among the most populous in the country [53].

In [7], GRIDCo published a number of medium-term planned projects. The medium-term projects to be completed within the 5-year tariff period (2022–2027) are expected to build a robust transmission system that enables reliable power delivery, minimizes system interruptions, lowers transmission losses, and meets increasing demand. These projects include constructing new transmission lines and substations, upgrading existing lines, installing reactive power compensators, installing new transformers, and upgrading SCADA systems. We focus on transmission line projects (new construction and upgrades) and compare these plans against the optimal transmission lines identified by our TNEP model.

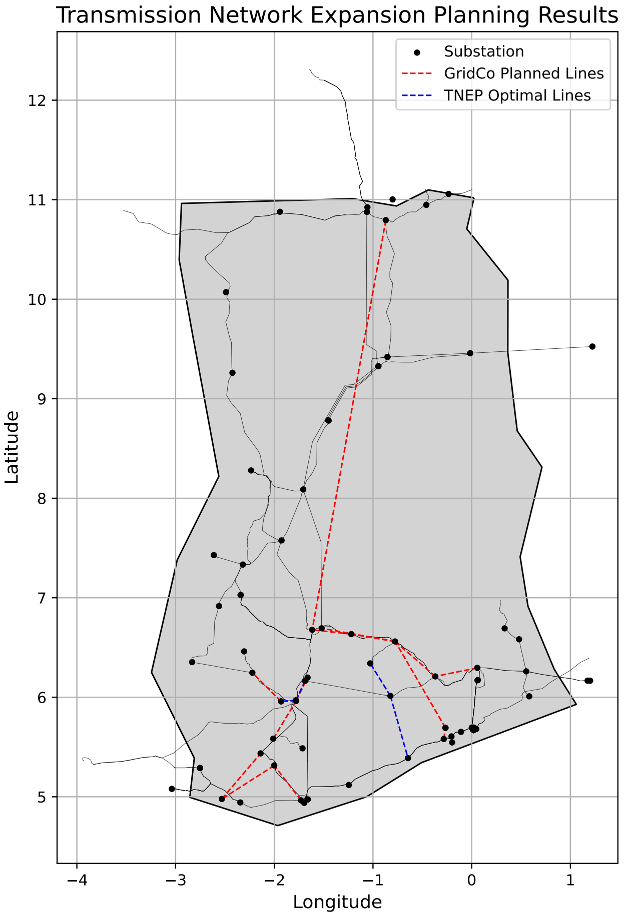

Fig. 5. Results of the Transmission Network Expansion Planning problem versus the GRIDCo planned transmission line projects.

The results in Figure 5 show that the TNEP results are similar to the planned transmission projects. First, Lines 1 and 2 of the TNEP are already included in the line upgrades planned by GRIDCo. More specifically, GRIDCo has planned a number of line upgrades in the central parts of Ghana, including upgrades to lines connecting the `Dunkwa`, `Ayanfuri`, and `New Obuasi` substations. Similarly, Lines 3 and 4, although not exactly the same, provide lines *parallel* to the lines planned. Our lines span from `New Abirem`, through `Akwatia` to `Winneba`, while GRIDCo plans to construct lines from `Mallam`, through `PP330` to `Nkwawkaw`. Although not exactly the same lines, these two are basically parallel as seen in Figure 5

These results provide a partial validation of the fidelity of the synthetic grid model. Our identified lines include only a subset of all of GRIDCo's planned line construction projects. This deviation between the proposed projects and the TNEP solution could result from several factors. For instance, our TNEP model uses a shortest-path formulation for the candidate lines, which may not always align with the routing GRIDCo would plan. Furthermore, the projects outlined in [7] have multiple motivations, e.g., increasing reliability, reducing transmission losses, and meeting rising electricity demand, while our TNEP formulation focuses only on meeting projected growth in electric demands. Thus, the lines we identify represent only a subset of GRIDCo's transmission line projects. Nevertheless, the observation that the key lines identified by our TNEP analysis shared a spatial alignment with GRIDCo's planned projects helps support the validity and usefulness of the synthetic Ghana grid.

VII. Conclusion

Synthetic grids provide significant value to the power systems research community by enabling experiments that address region-specific issues and policies. In this paper, we validated the realism of a synthetic grid model developed for Ghana via two studies: a network reliability assessment and a transmission network expansion planning problem.

We compared results from both studies obtained using the synthetic grid model with those from real blackout data and from GRIDCo's proposed expansion planning projects. Despite being constructed using only publicly available data, the critical lines from our reliability study are consistent with the actual lines where failures have caused significant power outages in reality. Additionally, the lines our TNEP results identified as optimal expansion decisions exhibited an overall spatial alignment with a subset of GRIDCo's planned transmission projects.

These findings help to validate the realism of the synthetic Ghana grid and are clear examples demonstrating the value of developing synthetic grids beyond the United States and Europe. The characteristics of the Ghana system that enable the validation approaches in this paper are shared across many developing countries, and a realistic model like this enables researchers to develop solutions most suited to these regions.

Our ongoing work is creating additional synthetic models for other developing countries and assessing further validation methods. We also aim to move beyond steady-state representations by developing models that account for the dynamic behavior of electric grids.

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