AC Power Flow-Based Co-Optimization for Integrated Generation and Transmission Network Expansion Planning

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***Abstract*—The integrated Generation and Transmission Network Expansion Planning (GTNEP) models have been developed to enable simultaneous investment decisions that consider both investment and operational components. In this research, a new methodology to assess the GTNEP is proposed, which takes into account the integrated planning of new generation power plants, transmission lines, reactive power allocation, and network power losses. To address the GTNEP, the operational problem is formulated using the AC optimal power flow, providing more realistic solutions. As a solution method, the Iterated Greedy Algorithm (IGA), and a hybridization of differential evolution with the tabu search (DE-TS) meta-heuristic were implemented. The proposed approach was tested using the 6-bus Garver test system. The results demonstrate that more cost-effective and realistic expansion plans are found with integrated AC-GTNEP compared to the sequential approach of first solving Generation Expansion Planning (GEP), and then Transmission Network Expansion Planning (TNEP).**

***Index Terms*—Generation Expansion Planning, Transmission Expansion Planning, Co-optimization, Integrated planning.**

I. Introduction

THE integrated Generation and Transmission Network Expansion Planning (GTNEP) aims to ensure a reliable and resilient energy supply by simultaneously identifying the optimal timing, types, and locations for new generation units and transmission elements required to meet long-term energy needs, taking into account environmental and economic viability. Typically, GEP and TNEP have been addressed sequentially [1], with GEP being solved first, and the resulting expansion plan is then used to address TNEP. This approach disregards the fact that the allocation of new generation units is influenced by the availability of the transmission network and that the placement of new generation units directly influences transmission expansion planning. Consequently, the benefits of GTNEP can be summarized as follows: (i) it allows the assessment of the interdependence that exists between the transmission network and the quality of non-renewable resources, (ii) it enables the integration of generation and transmission with other emerging technologies, (iii) it links the power system with electrical markets, and (iv) it results in improved expansion plans in terms of cost-effectiveness.

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In the early stages of research for the GTNEP problem, the transmission network was represented through mathematical formulations of linear power flow as the transportation model [2], or the direct current (DC) model [3]. The disadvantage of this linear approximation is the loss of model fidelity since it does not consider important features such as the proper evaluation of losses, voltage variables, and constraints related to reactive power limits. Therefore, the expansion solutions derived from this approach must be verified using a complete AC model to ensure network security requirements. Linearized AC models have also been applied to GTNEP, as in [4] and [5]. However, in the case of [4], the omission of transmission line resistance leads to an underestimation of power losses in the system. Therefore, considering the complexity of the current electrical infrastructure, this study utilizes the complete AC model to address the operational challenges of the GTNEP, providing a more comprehensive and realistic representation of the system.

When addressing the GTNEP, the prevailing approach in most research works is to employ linearized models, solved by mathematical optimization-based methods [3]. However, linearized models only provide underestimated investments, which are not very useful for real-world applications. Therefore, the use of full AC models can overcome that issue, where meta-heuristic techniques have demonstrated their effectiveness and superiority over traditional optimization methods, as proven in [6]. In a few research works, meta-heuristics techniques are applied to solve the GTNEP, such as [7] and [8] where the Gradient-Genetic and the Genetic-Tabu Hybrid Algorithms were used to solve linear models, respectively.

In this research, the Iterated Greedy Algorithm (IGA), and a hybridization of differential evolution with the tabu search (DE-TS) meta-heuristic were implemented to solve the GTNEP problem. The full AC power flow model is adopted to study the impact of network power losses, reactive power compensation, and the long-term planning of new power plants and new transmission lines. Additionally, reliability criteria such as Loss of Load Probability (LOLP) are formulated as annual constraints to ensure reliable operation.

The remainder of this work is organized as follows: Section II presents the GTNEP mathematical model, while Section III describes the DE-TS and IGA meta-heuristics implemented to solve the GTNEP problem. Finally, results and conclusions are shown in Section IV, and V respectively.

II. GTNEP Mathematical Model

The mathematical model of integrated GTNEP involves solving two problems: (i) the master problem (MP), which minimizes the investment cost of new power plants, including the cost obtained in the sub-problem (SP), and (ii) the sub-problem, which provides the investment costs of transmission lines, reactive power compensation, and network power losses to the master problem.

A. Master problem

In equation (1), the objective function aims to minimize the total generation investment cost (GIC), as defined in equation (2). This cost is computed by considering overnight costs (OC), interest during construction (IDC), generation capacity (GC), and a binary variable u indicating whether power plant type m is constructed in bus i. The objective function also includes the investment and operational costs of the sub-problem ω, as defined in equation (11).

$$\min\ \upsilon = GIC + \omega \tag{1}$$

$$GIC = \sum_{i \in \Omega} \sum_{m \in \Lambda} \left(OC_{(m)} + IDC_{(m)} \right) \cdot GC_{(m)} \cdot u_{(m,i)} \tag{2}$$

The constraints presented in equations (3) and (4) emphasize the relationship between the demand P^d and the generation capacity of new power plants type m, allocated at bus i ($GC_{(m,i)}$). They also consider a minimum and maximum percentage reserve margin ($\underline{R}, \overline{R}$). In these equations, $GC^{'}_{(i)}$ represents the existing generation capacity at bus i.

$$(1 + \underline{R}) \cdot P^d \leq \sum_{i \in \Omega} \sum_{m \in \Lambda} GC_{(m,i)} \cdot u_{(m,i)} + GC^{'}_{(i)} \tag{3}$$

$$\sum_{i \in \Omega} \sum_{m \in \Lambda} GC_{(m,i)} \cdot u_{(m,i)} + GC^{'}_{(i)} \leq \left(1 + \overline{R} \right) \cdot P^d \tag{4}$$

$$\sum_{i \in \Omega} \left(F^{'}_{(f,i)} + \sum_{m \in \Lambda} TF_{(f,m)} \cdot E_{(m,i)} \cdot u_{(m,i)} \right) \leq \overline{F}_{(f)} \quad \forall f \in \Omega_f \tag{5}$$

$$\sum_{i \in \Omega} \left(Y^{'}_{(p,i)} + \sum_{m \in \Lambda} TE_{(p,m)} \cdot E_{(m,i)} \cdot u_{(m,i)} \right) \leq \overline{Y}_{(p)} \quad \forall p \in \Omega_p \tag{6}$$

$$LOLP \leq \overline{LOLP} \tag{7}$$

$$\sum_{m \in \Lambda} u_{(m,i)} \leq 1 \quad \forall i \in \Omega \tag{8}$$

$$u_{(m,i)} = \{0, 1\} \qquad \forall m \in \Lambda, \forall i \in \Omega \tag{9}$$

The equation (5) specifies that the quantity of fuel of type f must be less than or equal to the maximum available fuel quantity $\overline{F}_{(f)}$. Similarly, equation (6) represents the constraint related to the amount of pollution type p that can be emitted, and this quantity should not exceed the established maximum limit $\overline{Y}_{(p)}$. The constraint presented in equation (7) establishes that the Loss of Load Probability (LOLP) should not exceed the upper limit $\overline{LOLP}$. Equation (9) ensures that the decision to construct a generating unit is binary. Finally, equation (8) indicates that only one candidate power plant can be allocated to bus i. In these equations, $F^{'}_{(f,i)}$ and $Y^{'}_{(p,i)}$ represent the existing consumption of fuel type f and the existing emission of pollution type p at bus i, respectively. $TF_{(f,m)}$ and $TE_{(p,m)}$ denote the consumption rate of fuel and the emission rate of pollution for power plant type m, while $E_{(m,i)}$ is the energy produced by the power plant type m allocated at bus i.

$$LOLP = \sum_{\kappa \in \Delta} p_\kappa \cdot t_\kappa = \sum_{\kappa \in \Delta} P_\kappa \cdot (t_\kappa - t_{\kappa-1}) \tag{10}$$

The LOLP is calculated using equation (10), in which p_κ, P_κ, and t_κ represent the probability, cumulative probability, and the period of lost load during generation outage κ. The LOLP is computed using the forced outage rate (FOR) of each power plant, and a Load Duration Curve (LDC), following the process described in [9].

B. Sub-problem

The sub-problem involves solving the TNEP problem, which is further divided into two parts: (i) the expansion problem and (ii) the operational problem.

1) Expansion problem: The primary objective of this problem is to minimize the total cost, which includes the expansion cost (C_{exp}) (12), operational cost (C_{op}) (16), and network power losses cost (C_{loss}) (13).

$$\min\ \omega = C_{exp} + C_{op} + C_{loss} \tag{11}$$

$$C_{exp} = \sum_{(i,j) \in \Gamma} c^L_{(i,j)} \cdot n_{(i,j)} + \sum_{i \in \Omega} \varphi^q_{(i)} \cdot Q^c_{(i)} \tag{12}$$

$$C_{loss} = hr \cdot f_{loss} \cdot \varphi^{loss} \cdot \sum_{(i,j) \in \Gamma} P^{from}_{(i,j)} + P^{to}_{(i,j)} \tag{13}$$

$$0 \leq n_{(i,j)} \leq \overline{n}_{(i,j)} - n^0_{(i,j)} \quad \forall i, j \in \Gamma \tag{14}$$

$$n_{(i,j)} \in \mathbf{Z} \quad \forall i, j \in \Gamma \tag{15}$$

In equation (12), $c^L_{(i,j)}$ represents the cost of adding a new transmission line between the right-of-way (i, j), $n_{(i,j)}$ indicates the number of added lines, $\varphi^q_{(i)}$ and $Q^c_{(i)}$ represent the cost and the required reactive power compensation. In equation (13), hr stands for the number of hours in a year, f_{loss} represents the loss factor, φ^{loss} is the cost of losses, and $P^{from}_{(i,j)}$ and $P^{to}_{(i,j)}$ denote the power flow in the circuit between buses i and j. Constraints are related to the maximum number of lines that can be added in each right-of-way (14) and the integer nature of the added lines (15).

2) Operational problem: The operational problem provides the cost of active load shedding and the annual energy production cost to the expansion problem. To address the operational problem, the AC optimal power flow is used. This formulation considers in the objective function (16) the active load shedding $P^c_{(i)}$ and its price $\varphi^p_{(i)}$, as well as the cost of energy production. The energy price is computed using the equation (17) that is the Levelized Cost of Electricity (LCOE)

[10], which represents the minimum average price required for the electricity generated by the asset to break even over its lifetime.

$$\min\ C_{op} = \frac{S^b}{10^6} \cdot \left(\sum_{i \in \Omega} \varphi^p_{(i)} \cdot P^c_{(i)} + hr \cdot \sum_{i \in \Omega} LCOE_{(i)} \cdot P^g_{(m,i)} \right) \quad (16)$$

$$LCOE_{(i)} = \sum_{m \in \Lambda} \psi_{(m)} \cdot \left(\frac{CRF_{(m)} \cdot C_{inv(m)}}{hr \cdot \psi_{(m)}} + C_{OMF(m)} + C_{OMV(m)} + {}^1/_{\eta_{(m)}} \cdot CF_{(m)} \cdot TF_{(m)} + {}^1/_{\eta_{(m)}} \cdot P_{CO2(m)} \cdot TE_{(m)} \right) \quad (17)$$

$$CRF_{(m)} = \frac{\alpha \cdot (1+\alpha)^{\Upsilon_{(m)}}}{(1+\alpha)^{\Upsilon_{(m)}} - 1} \quad (18)$$

The active and reactive power balance at each bus of the system as defined by equations (19) and (20), respectively.

$$P^g_{(i)} = \sum_{(i,j) \in \Omega_l} P^{from}_{(i,j)} + \sum_{(i,j) \in \Omega_l} P^{to}_{(i,j)} + g^{sh}_i V^2_{(i)} + P^d_{(i)} - P^c_{(i)} - P^g_{(m,i)} \quad \forall i \in \Omega \quad (19)$$

$$Q^g_{(i)} = \sum_{(i,j) \in \Omega_l} Q^{from}_{(i,j)} + \sum_{(i,j) \in \Omega_l} Q^{to}_{(i,j)} - b^{sh}_i V^2_{(i)} + Q^d_{(i)} - Q^c_{(i)} - Q^g_{(m,i)} \quad \forall i \in \Omega \quad (20)$$

The limits of apparent power flow through the lines are represented by constraints (21) and (22), ($\forall i, j \in \Gamma$):

$$\left(P^{from}_{(i,j)}\right)^2 + \left(Q^{from}_{(i,j)}\right)^2 \leq \left(\left(n_{(i,j)} + n^0_{(i,j)}\right) \overline{S}_{(i,j)}\right)^2 \quad (21)$$

$$\left(P^{to}_{(i,j)}\right)^2 + \left(Q^{to}_{(i,j)}\right)^2 \leq \left(\left(n_{(i,j)} + n^0_{(i,j)}\right) \overline{S}_{(i,j)}\right)^2 \quad (22)$$

Constraints (23) - (26) represent the maximum and minimum limits for active power, reactive power, load shedding, voltage magnitudes, and phase angles, ($\forall i \in \Omega$):

$$\underline{P}_{(i)} \leq P^g_{(i)} \leq \overline{P}_{(i)} \quad (23)$$

$$\underline{Q}_{(i)} \leq Q^g_{(i)} \leq \overline{Q}_{(i)} \quad (24)$$

$$\underline{V}_{(i)} \leq V_{(i)} \leq \overline{V}_{(i)} \quad (25)$$

$$-\frac{\pi}{2} \leq \theta_{(i)} \leq \frac{\pi}{2} \quad (26)$$

The set of constraints (27) - (30), represents the maximum and minimum capacities for active and reactive power generation, either by candidate or fictitious generators, ($\forall m \in \Lambda,\ \forall i \in \Omega$):

$$\left(1 - u_{(m,i)}\right) \cdot \underline{P}^c_{(i)} \leq P^c_{(i)} \leq \overline{P}^c_{(i)} \cdot \left(1 - u_{(m,i)}\right) \quad (27)$$

$$\left(1 - u_{(m,i)}\right) \cdot \underline{Q}^c_{(i)} \leq Q^c_{(i)} \leq \overline{Q}^c_{(i)} \cdot \left(1 - u_{(m,i)}\right) \quad (28)$$

$$u_{(m,i)} \cdot \underline{P}_{(m,i)} \leq P^g_{(m,i)} \leq \overline{P}_{(m,i)} \cdot u_{(m,i)} \quad (29)$$

$$u_{(m,i)} \cdot \underline{Q}_{(m,i)} \leq Q^g_{(m,i)} \leq \overline{Q}_{(m,i)} \cdot u_{(m,i)} \quad (30)$$

In equation (16), S^b is the base power, α is the annual discount rate, $\Upsilon_{(m)}$ represents the lifetime of the candidate power plant type m, and $P^g_{(m,i)}$ is the active power supplied by power plant type m allocated at bus i. In equation (17) $\psi_{(m)}$ represents the capacity factor, $\eta_{(m)}$ is the electrical efficiency of power plant type m, CRF is the capital recovery factor computed through equation (18), $C_{inv(m)}$, $C_{OMF(m)}$, $C_{OMV(m)}$, $CF_{(m)}$, and $P_{CO2(m)}$ correspond to the unit costs associated with the investment in new power plants, fixed and variable operating costs, fuel cost, and the unit price of CO_2 emissions, respectively. Finally, the expressions for $P^{from}_{(i,j)}$, $P^{to}_{(i,j)}$, $Q^{from}_{(i,j)}$, and $Q^{to}_{(i,j)}$ in equations (19) - (22) can be found in [11]. It is important to note that n is specified as an integer variable and u is identified as a binary variable. Other variables are considered continuous unless explicitly specified otherwise.

III. Solution method

As proven in [6], meta-heuristic techniques have demonstrated their superiority over traditional mathematical optimization methods when applied to the AC TNEP problem. Meta-heuristics consistently produce low-cost feasible solutions within reasonable computing times. Also, those techniques hold the added advantage of potentially reducing computing time through parallel processing, a challenge for mathematical-based optimization methods. In this work, the Iterated Greedy Algorithm (IGA) was implemented to solve the GTNEP sub-problem, while the meta-heuristic Differential Evolution with Tabu Search (DE-TS) was implemented to solve the GTNEP master problem.

A. Differential evolution - tabu search

The DE-TS structure is defined in four stages: Initialization, Mutation, Recombination, and Selection. These stages have been designed to implement the DE/rand/1/bin variation [12]. In the Initialization phase, a population of dimension D (number of candidate buses to allocate new power plants) and N individuals, is randomly generated. After the Initialization phase, the population is evaluated, and then a tabu list is created and updated to store the best individuals found in the current iteration. Following this, the mutation and recombination process is performed. If the new vector is in the tabu list, a 2-opt move is executed to modify the individual, which is then evaluated. Finally, the best individual is selected, and the tabu tenure of all vectors in the tabu list is reduced.

Figure 1 displays the flowchart of the DE-TS algorithm as applied to the GTNEP problem. It also illustrates the evaluation process for each individual, which begins with updating the test system generation data corresponding to the x_i individual. Subsequently, the GTNEP master problem constraints are evaluated. If x_i satisfies these constraints, the LCOE is calculated, the test system data is updated, and the GTNEP sub-problem is solved. Finally, the objective function of the GTNEP master problem is computed.

B. Iterated greedy algorithm

The algorithm structure is outlined in four main phases: *i.* initialization, *ii.* destruction, *iii.* construction, and *iv.* acceptance criterion. The initialization involves generating an initial solution using a constructive heuristic (forward). During the destruction phase, some components of the candidate solution are removed. Subsequently, the construction procedure employs a constructive heuristic (forward) to reconstruct the previously destructed candidate solution. Once a candidate solution is completed, an acceptance criterion determines whether the newly constructed solution should replace the existing one. The IGA has already been applied to solve the TNEP problem. Details and settings of this meta-heuristic applied to the TNEP problem can be found in [13].

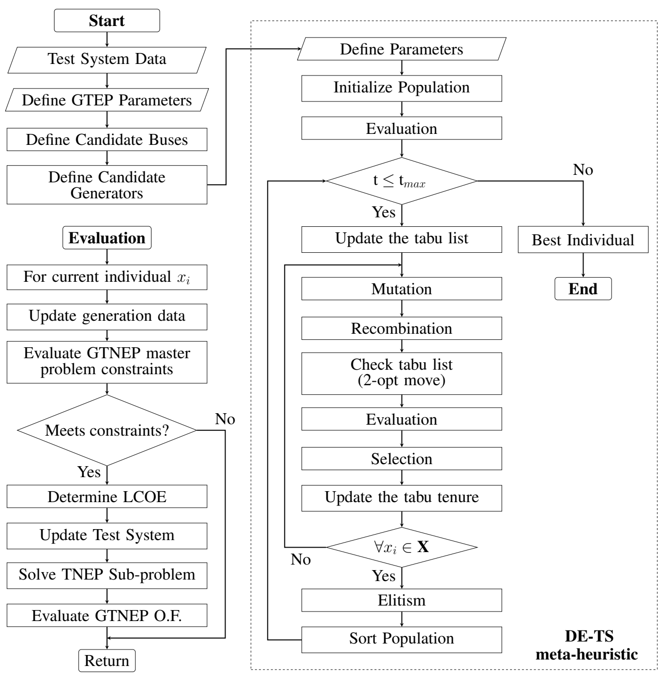

Figure 1. DE-TS Hybrid Meta-heuristic applied to the GTNEP problem.

IV. Results

The proposed methodology is evaluated using the 6-bus Garver test system. The approach was implemented using the Julia programming language running on an Intel i7, 3.60 GHz, 16GB RAM, hardware platform. The data for the candidate generation power plants, presented in Tables I and II, can be seen in [10]. For all tests, the following data were assumed: $\alpha = 10\%$, $\underline{R} = 15\%$, $\overline{R} = 45\%$, $hr = 8760$, $\overline{LOLP} = 1.5\%$. In the tests, no consideration was given to the maximum fuel limits and CO_2 emissions limits. Furthermore, the operation and maintenance costs of existing generation units were not taken into account. The load duration curve used to determine the LOLP is defined in Equation (31).

$$P^d_{norm} = 1 - 3.2 \cdot (t_d) + 16.6 \cdot (t_d)^2 - 36.8 \cdot (t_d)^3 + 36 \cdot (t_d)^4 - 12.9 \cdot (t_d)^5 \quad (31)$$

The maximum limit for reactive power sources was considered to be $\overline{Q}_{(i)} = 100$ Mvar, with a cost of $\varphi^q_{(i)} = 0.025$ MUSD/Mvar. The voltage magnitude limits were $\overline{V} = 1.05$ p.u. and $\underline{V} = 0.95$ p.u. The maximum active power limit for the fictitious generators was considered to be $\overline{P}^c_{(i)} = 1000$ MW. However, the cost $\varphi^p_{(i)}$ was considered to be high, aiming to achieve an expansion plan where active power shedding is approximately zero, $P^c_{(i)} \approx 0$.

A. Garver test system

The system consists of 6 buses, a total active power demand of 760 MW, and 152 Mvar of reactive power. It offers 15 candidate paths for the addition of new transmission lines. The installed active power capacity is 1,140 MW, while the reactive power capacity ranges between -30 Mvar and 332 Mvar. The maximum number of lines that can be added in each path, ($\overline{n}$) is 5. The data for this system can be found in [11].

Table I
Conventional generation: technical and economic features.

Technology Type	Coal (Lignite)-A	Natural Gas (CCGT)-B	Natural Gas (OCGT)-C
Capacity (MW)	600	500	600
Overnight Cost (USD/kW)	2189.486	957.900	738.952
Fixed O&M Costs (USD/MWh)	8.6	13.31	16.71
Variable O&M Costs (USD/MWh)	3.2	2.31	2.00
Coal Price (USD/ton)	51	NR	NR
Natural Gas Price (USD/MBtu)	NR	3.2	3.2
Carbon Price (USD/ton of CO_2)	30	30	30
Calorific Value (kcal/kg)	4063.6	NR	NR
CO_2 Emission Factor (tons/TJ)	101.00	56.10	56.10
Efficiency (%)	34	58	44
Capacity Factor (%)	85	85	44
Lifetime (years)	40	30	30
FOR (%)	9.0	11.0	10.0
Construction Years	4.0	3.0	2.0

NR: not required for the power plant.

Table II
Renewable generation: technical and economic features.

Technology Type	Solar (PV) D	Onshore wind E
Capacity (MW)	100	100
Overnight Cost (USD/kW)	1197.375	1314.692
Fixed O&M Costs (USD/MWh)	6.48	5.98
Variable O&M Costs (USD/MWh)	0	0.02
Capacity Factor (%)	31	47
Lifetime (years)	25	25
FOR (%)	6.0	5.0
Construction Years	1.0	1.0

1) case A1: In this case study, two scenarios using the base case data are explored: scenario A1.1, which does not include the allocation of reactive power compensation, and scenario A1.2, which considers the allocation of reactive power sources in its formulation. The results are shown in Table III. For these two scenarios, there is no need to add new generation units, as the current generation meets the test system's requirements. It can be seen that this case corresponds solely to a TNEP problem, and the results agree with those obtained in [11].

2) Case A2: In this case, 100 MW were added to each load bus, and power plants A, B, D, and E were considered as candidate ones. In this context, scenario A2.1 considers the integrated GTNEP, while scenario A2.2 addresses the sequential study of GEP and TNEP, considering reactive power compensation in both cases. As shown in Table III, in scenario A2.1, power plant type D was constructed in bus 4 ($u_{D,4} = 1$), and type B in bus 5 ($u_{B,5} = 1$), resulting in total savings of 21.51 MUSD compared to the sequential study scenario A2.2. The latter requires an additional transmission line l_{3-5}, reactive power compensation of $Q^c_5 = 49.99$ Mvar, and also experiences higher power losses. Additionally, the sequential study requires less time because it does not consider the TNEP

Table III
RESULTS FOR INTEGRATED GENERATION AND TRANSMISSION NETWORK EXPANSION PLANNING

Scenario	A1.1	A1.2	A2.1	A2.2	A3.1	A3.2
Added lines	$l_{2-6}=2$ $l_{3-5}=2$ $l_{4-6}=2$	$l_{2-6}=1$ $l_{3-5}=1$ $l_{4-6}=2$	$l_{2-6}=3$ $l_{3-5}=1$ $l_{4-6}=2$	$l_{2-6}=3$ $l_{3-5}=2$ $l_{4-6}=2$	$l_{2-3}=1$ $l_{2-6}=1$ $l_{4-6}=3$	$l_{2-6}=3$ $l_{3-5}=2$ $l_{5-6}=2$
Power plants required	-	-	$u_{D,4}=1$ $u_{B,5}=1$	$u_{D,2}=1$ $u_{B,4}=1$	$u_{C,5}=1$	$u_{C,4}=1$
Shunt compensation (MVar)	-	$Q_5^c=49,43$	0.0	$Q_5^c=49,99$	-	-
Power losses (MW)	12,41	14,88	23.38	26.56	17.59	21.37
Line cost (MUSD)	160	110	170	190	140	252
Shunt compensation cost (MUSD)	-	1,24	0.0	1.25	-	-
Power losses cost (MUSD)	6.68	8.01	12.58	14.30	9.47	11.50
Generation investment cost (MUSD)	-	-	680.17	680.17	488.82	488.82
Energy cost (MUSD)	-	-	67.46	66.00	82.97	64.86
Total cost (MUSD)	166.68	111,24	930.21	951.72	721.26	817.18
Time (h)	7.53	3.92	2.70	0.76	3.31	0.96
O.F. Evaluations (Sub-problem)	147702	102567	69190	1240	74628	1721
O.F. Evaluations (Master problem)	311	194	69	138	81	113

in each iteration. As a result, there is a higher number of objective function evaluations for the sub-problem in scenario A2.1 compared to A2.2.

3) Case A3: Finally, in this case study, an additional 100 MW was considered for each load bus. All power plants were simultaneously considered as candidate options, and no reactive power compensation was taken into account. In this way, scenario A3.1 addresses the integrated GTNEP, and scenario A3.2 addresses the sequential problem, first GEP and then TNEP. In these two scenarios, power plant type C needs to be installed at bus 5 ($u_{C,5} = 1$) for scenario A3.1 and bus 4 ($u_{C,4} = 1$) for scenario A3.2. As can be seen in Table III, total savings of approximately 96 MUSD were obtained with integrated planning.

V. CONCLUSIONS

In this research the integrated generation and transmission network expansion planning was addressed, considering the joint planning of new power plants, transmission lines, reactive power sources, and network power losses. The results indicate that more economical expansion plans are achieved with integrated planning, primarily due to the reduced construction of transmission lines, influenced by the allocation of power plants in the system. This also holds for expansion plans, whether reactive power planning is considered. As a consequence, it is concluded that the interdependence between generation and transmission investments must be taken into account when evaluating any expansion project, whether for generation or transmission systems.

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