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Transmission System Expansion Plan, Methodologies, Framework, and Financial Appraisal Parameters: A review

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ABSTRACT: The continuous growing load demands call for timely and effective transmission system expansion planning (TEP). This expansion planning can be categorized as short term, encompassing 10 or fewer years and long term, covering more than fifteen years, with each having its own merits and demerits. This paper explores various research papers to get insight into expansion plans approaches, decision-making algorithms/strategies employed in these approaches, and dig out the best strategies. The important aspects to contemplate in these approaches are engineering aspects, legal modalities, cost-benefit analysis, the level of the incursion of Renewable Energy, theinclusion of new technologies, such as HVDC, and system reliability. In light of these expansion planning methodologies, recommendations will be imparted to effectively do the grid system expansion for any transmission system operator (TSO). Moreover, the expansion plan cost estimation elements thereafter, investment appraisal techniques have been highlighted to make a comprehensive plan that is technically and financially viable. The expansion planning approaches pose various challenges to the planners. These include varying but uncertain future load demands, availability of ample capital to achieve the desired expansion level, minding environmental impacts, regulatory and licensing-related challenges, ensuring controllability/reliability after renewable penetration, etc. This paper encompasses these aspects while suggesting the best strategies for expansion planning.

Keywords: Transmission system, expansion, planning, cost estimation, investment evaluation.

I. INTRODUCTION

The electric power transmission system was built to link remote power stations to end load centers. This allows power generation authorities to install electric power plants at far and feasible locations. The system's growth brings mesh of transmission system to ensure a smooth and reliable electrical power supply. The reliable and vast transmission system in a country fosters a better and diverse generation system. Therefore, it is justified to expand the transmission system to fulfill growing load demands with a cheaper and reliable generation/transmission system [1]. The Transmission Expansion Planning (TEP) gives the idea about how many new T/Lines to be added when added, i.e., time frame and where to be added, i.e., location to address future supply-demand needs.

The expansion approach must consider all the present and future challenges, short-term and long-term demand/supply forecasts, cost-benefit investigations, dependability, and network reliability.

Based on planning purview, the TEP approaches can be categorized into Static (focusing on single period planning) and Dynamic (keeping in view multiple periods) planning. Keeping in view the time frame, TEP can be classified as; short term (up to 10 years), medium-term (encompassing 10-20 years), and long term (covering 20-30 years). This is summarized in Fig. 1. In order to address the Transmission Expansion Planning problem, the solution approaches are generically classified as; Classical/heuristic and Non-classical/meta-heuristic [2].

The classical or heuristic methods use linear, quadratic, dynamic, Mixed Integer Programming (MIP) & Mixed-Integer Nonlinear Programming (MINLP), Benders' decomposition algorithm, branch bound method, etc., with each having its pros and cons and applications. Due to its ability to aptly handle the DC power flow (DC PF), the MIP is the frequently employed practice in the purview of classical methods. On the other hand, MINLP has the ability to cope with the nonlinearities of AC Power Flows. Nevertheless, the classical approaches are employed to evaluate an extracted solution instead of looking for the optimalplan. These methods work by converting power system equations intooptimization programming models. Although they usually lead to accurate solutions with apposite convergence, these modelsbecome burdensome as the power system scale expands. Any change/alteration in the system demands reorganization of the model [3].

To cover the discrepancies of classical methods, non-classical, also known as meta-heuristic approaches, have been proposed. These approaches/methodsinclude; Genetic algorithm, Expert system, Harmony, Tabu & Greedy Randomized search methods, Simulated Annealing, Ant Colony Optimization, Particle Swarm Intelligence, Grey Wolf Optimization, and Differential Evolution,etc.

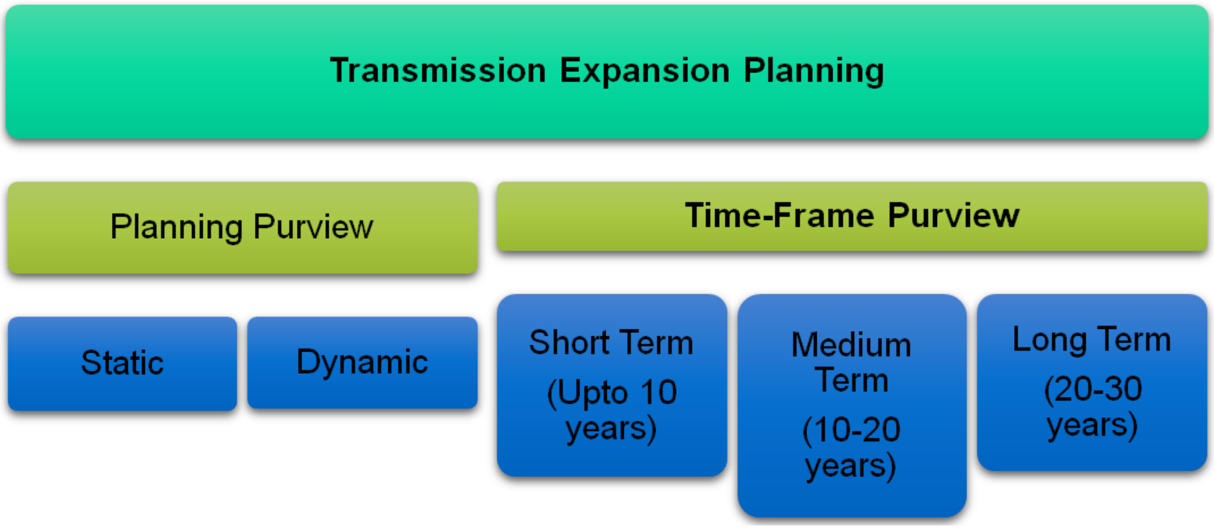

Fig. 1. Classification of TEP.

However, a meta-heuristic approach leads to an approximate solution by creating aheuristic (partial search algorithm). Moreover, these methods are simple, straightforward, and have superior convergence & computational execution [4].

The most common practice to plan a transmission system is to plan for 10 years and less. The short-term plans are easy to implement as these plans usually consider extending the present system. The need for a new right-of-way of the transmission system is avoided, and the existing system is extended. This extension has been done by reconductoring with better thermal and electrical capacity conductors; new parallel lines are also added in this expansion plan. This approach has its own merits and demerits, but the major merit is that it is fast to implement, and approvals are easy to get from the authority. The demerits of this short-term plan include the hurdles in extending the present network and some security problems overextending the path to a greater degree. Also, the old paths have some issues of connectivity; new power generation systems and load centers demand a new transmission system. Therefore, new topologies must be proposed with the existing network for better reliability and transporting power to new sectors. For that, a long-term plan is required i.e., from 15 to 20 years [5].

The old transmission system expansion plans are given in various research papers, such as in [1] traditional transmission expansion. The research explains how there is a regulated monopoly in old times where one utility is responsible for the generation, transmission, and distribution of electricity. It forecasts future load demand and proposes an expansion plan based on cost analysis and reliability. Afterward, the transmission expansion candidates are finalized based on detailed financial analysis, impact assessment, and power system operation simulations. The research also discusses the expansion of the transmission system in a restructured environment. The restructured environment places transmission expansion into two categories; one is transmission investment which is responsible for the problems associated with the investment of transmission candidates. The main factor for investment is to work out the cost and revenue relationship and decide whether to invest in a candidate or not. The other category is purely planning, which includes the technical impact on the system's reliability and considers economic and environmental impact assessments.

The short-term expansion plan has been revealed for three to five years; the proposed plan has three rules based on MW, MVAR, and ampacity [6]. As suggested in the paper, reactive power management is necessary for load voltage control, which is the most challenging task. Novel changes in the fast decoupled load flow (FDLF) algorithm are proposed, which enables on-the-fly reactive power management. The enhanced algorithm detects load flow divergence and has the self-correction feature by restarting itself automatically for reactive power control. The proposed method is implemented on the Indian Transmission system of 28000 MW with 1200 nodes. The grid expansion of the 230kV substation methodology was given by Dalal *et al.,* [7]. The methodology includes all engineering aspects while features like community outreach, legal approvals, etc., are neglected. The main features included in this study are; determining minimum requirements of transformers, line bays, specific space, and access restrictions, it also includes the calculation of new continuous and fault current ratings. Furthermore, evaluation of mechanical/thermal forces, protection/metering, available fault current limiters, grounding of the grid is also included. In addition to that, the assessment of effects on existing current interrupting devices, verification of control house building layout, DC system, SCADA communication system, lighting protection, and cost/benefit analysis are included. Fig. 2 explains the modern digital electrical power system, and Fig. 3 explains the challenges in the transmission system. The recent electrical transmission system expansion plans are ready to cope with all the transmission system challenges. The recent notable transmission expansion plans are discussed in this research, alongwith the cost estimation and investment evaluation plans. Section 3 of this paperexplains the transmission expansion plans discussed in various articles from 2016 to 2020-21 briefly, Section 4 discusses the cost estimation and investment evaluation parameters for transmission expansion, and Section 5 concludes the paper.

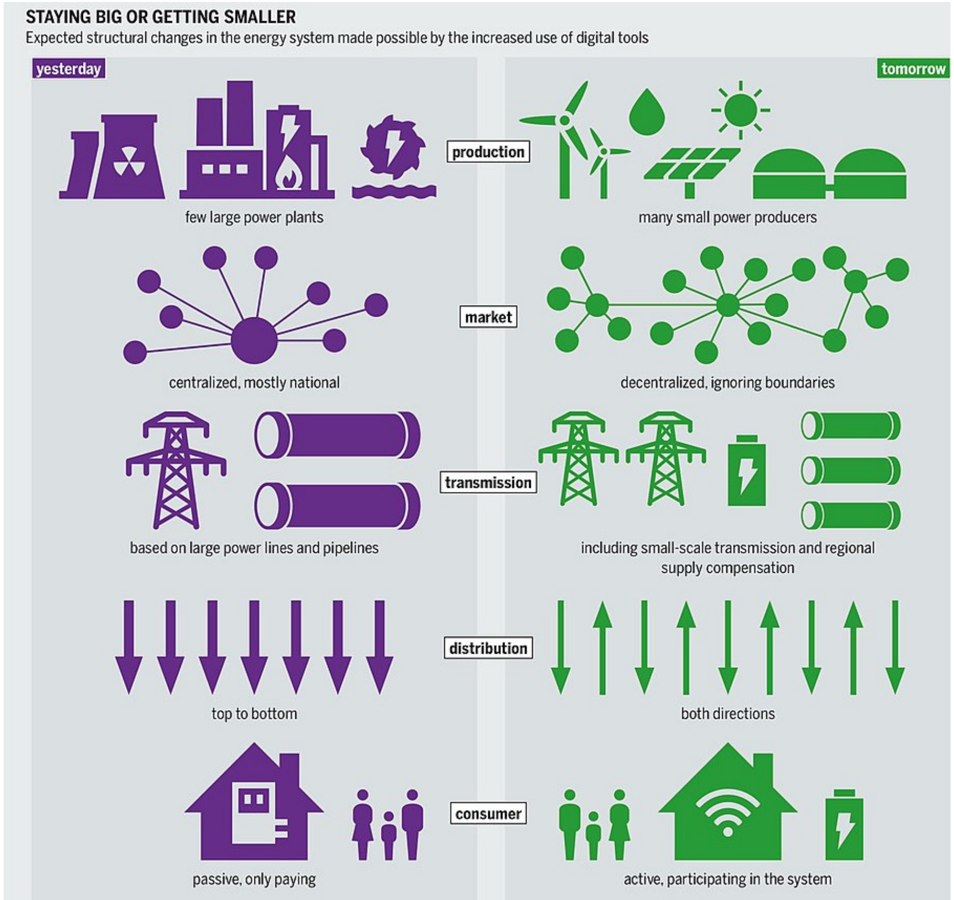

Fig. 2. Modern digital electrical power system [wikipedia.org].

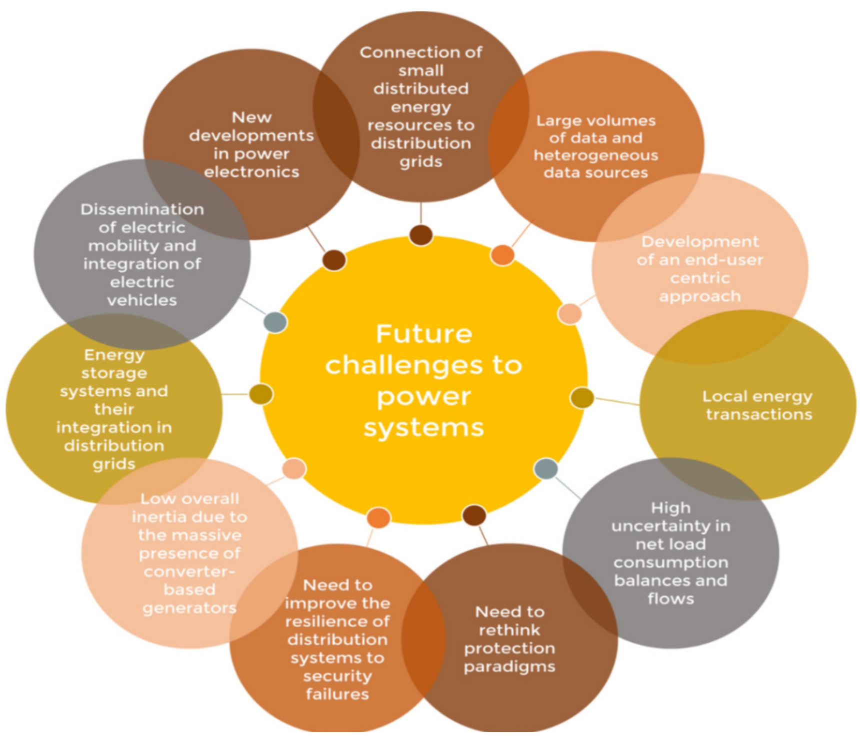

Fig. 3. Challenges in the ongoing transmission network.

II. TRANSMISSION SYSTEM EXPANSION PLANS FROM 2016 TO 2020

The transmission system expansion planning has taken a new level forthe last five years. Modern research is quite different from previous works. A short overview of all modern papers is mentioned below:

A. Multi-stage transmission expansion planning using Firefly Optimization Algorithm

In [8], A. Rastgouhas discussed the optimized multi-stage Transmission technique. The research has used the model[9]that has a multi-objective framework for transmission system expansion. The construction cost is the most important element of every framework. By using the firefly algorithm, it has three primary factors that needed to be addressed: the total planning cost, congestion cost, and cost of network reliability. The prime focus is to reduce costs and enhance its efficiency. Generally, congestion is a condition where the demand for transmission capacity surpasses the network capability. In this paper, both AC & DC transmission is addressed. This model has a 24 and 188 bus system and a 400KV transmission system. That shows that it can apply to a large transmission system with a high level of accuracy.

B. Optimizing generation/transmission expansion with wind-power in large-scale power grids

In [10], the high wind power generation penetration in the transmission network has been optimized by the model known as Mixed-integer-planning(MIP). This paper presents the variation and relationship of load and wind power across the localities with large-scale power grids. The main edge of this system is that the capacity and timing of transmission and generation expansion can be obtained by solving a single optimization problem. The scenario generation method deals with wind and demand diversity. The US eastern connection actual system data also verify this model. The result of the proposed model shows that it is a cost-effective system for transmitting energy to high loads with less wind potential, and MIP provides a more systematic generation and transmission expansion approach.

C. Transmission expansion planning using Artificial Intelligence

Fathy *et al.,* [11] researched the Optimal Transmission network for expansion planning(TNEP). This journal has addressed the importance of load prediction in any system that helps in optimal planning with better load forecasting. It stated that Mathematical programs of digital computers should form the plan because expenditures and investments of transmissions are huge & complex. These computer programs manage it more efficiently with small effort. According to the author, more advanced and artificial intelligence-based models like ANFIS (Adaptive Neuro-Fuzzy Inference System) can be employed for better load forecasting. The heuristic approach of TNEP utilized the basic fact that power flow is based on the response of network configuration, which is also determined by the effectiveness of the right-of-way defined. The power flow depends upon the position, type, and length concerning the main load center. This technique has several steps; the first step incorporatesthe differentiation of transmission routes by the existing route to the purposed route. The second step is to find the power flow across each line. The third is estimating the unit power cost on any transmission system. After that, reiterate the process by removing the worst line,and in theend, the least cost network will be obtained. Finally, 2^{nd}-degree polynomial fitting is used for forecasting load data, and the new formula is proposed. As a matter of fact, this technique is implemented on the Egyptian transmission system up to the year 2030, and after checking the statistical analysis, the results are declared satisfactory.

D. Bulk Power Transmission System Expansion Planning using Monte Carlo and Artificial Intelligence Techniques

Melodi *et al.,* [12] described an algorithm for a long-term transmission plan based on Monte Carlo and Artificial Intelligence-based technique. This method designs a Monte Carlo and artificial intelligence-based algorithm for a long-term transmission plan in the Nigerian transmission system. This system employs the annual peak load factor (LF), Gross domestic product (GDP), population, weather conditions, and complete details of annual load peak demands for 15 years. Population growth and GDP are also used as determining factors in this article. The relationship among these variables has been extracted by Multi-Regression Analysis (MRA). A regression load forecasting model was attained, which generated a Monte Carlo-based probabilistic prediction modelthat depicts time-step load distribution in a normal probabilistic manner. An auto-regression feed-forward network, which is nonlinear in nature, is achieved by employing an error backpropagation algorithm and takes the historical GDP as input for long-term horizonprediction in the Nigerian Transmission System. The ANN-based model converged withthe regression model within the Monte Carlo model boundaries. The time-step reactions/responses of the overall model proposed the need for strengthening the present NigerianTS and hence long-term expansion.

III. "SURVEY OF TRANMISSION EXPANSION PLANNING''

Lumbreras *et al.,* [13] discussed the upcoming requirements and challenges of transmission expansion that includes deregulation, renewable energy sources penetration, large-scale generation projects, market interpretation, regional planning, and long permitting processes. Generally, these are the important factors that have not been much talked about. However, this research has done important work to explain the underuse transmission practices, including the expansion plan of the Europe Network of Transmission System Operators (ENTSO). The paper describes its 10-year expansion plan in the purview of short-term planning. The second expansion plan discussed in the article is Project E-highway (7th Framework program). This targets the development of a method for Pan-European TEP from 2020 to 2050 (long term). The third German transmission expansion plan is Desertec that proposes about renewable generation permeation plan. The next plan is the French proposed plan called "Medgrid." There are many projects like Desertec, Medgrid Irene-40 (2008–2012), Offshore grid (2009–2011), SUSPLAN (2008–2010), Roadmap 2050. These are initiative plans of low carbon Europe (2013) to collaborate for the interconnection of European-super-grid. This research also addresses the transmission problem in a more interactive and automotive approach elaborating its pros and cons.

A. Large-scale Transmission Expansion Planning using Reduce-Expand-Develop Methodology

Lumbreras *et al.,* [14] emphasized avoiding such transmission expansion planning (TEP) that cannot be managed currently by optimization of the system on a large scale. It also discussed the "reduce-expand-develop"approach that helps to decrease the number of unmanageable full nodal networks to zonal networks. It depends on a proposed composite distance combining electrical and geographical distance but at the same time maintaining the key features and investment drivers as of the original network. With this modification, the system proposed by this research preserves the most important and relevant transmission branches known as critical branches. As a modular zonal expansion, these results are not implementable solely at zonal level expansion. There is a need to check the expansion solution in the nodal network because it is in line with the zonal plan as the development phase. So, this method is designed for large-scale systems, as described earlier. Its optimization develops a modular zonal expansion plan that reflects the most essential features of the whole system and can be translated into a directly implementable nodal expansion plan. This paper also proposes the inclusion of HVDC and phase-shifting transformer (PSTs) to the existing and new lines as expansion.

B. Transmission Expansion Planning Optimization improving RES integration on Electricity Market

Sima *et al.,* [15] inspect the transmission Expansion Planning (TEP) in the current Romanian power system. It uses the classical generating units with high sharing of Renewable energy sources (RES) such as a photodiode and wind energy. This paper explains the objective of lowering the load-shedding cost and betters the energy transmission between customers and producers. This study recommends that the TEP issue be resolved by supply-demand balance at the time of peak load, even during the breakdown. Furthermore, the study establishes a relationship between investment budget and a specific number of transmission systems by the General Algebraic Modeling System (GAMS). The target of this model is to make the system more cost-efficient with the construction of a new optimal line and reducedcost of load-shedding. The variation of budget decides the number of new transmissionswhich can be drawn in a new expansion plan and its effect on load-shedding. This model also confirms the decline in load-shedding by the reduction of the objective function. Hence, it reduces the operational costs of the power system as a whole.

C. Transmission Expansion Planning using Stochastic Programming Approach

Zhan *et al.,* [16] proposed a stochastic programming approach in the transmission system planning for the uncertainty problem of renewable energy sources and load. The scenario reduction technique has been used with the help of the Improved Forward Selection Algorithm (IFSA). Then, the stochastic transmission expansion planning is done with the help of the Benders Decomposition Algorithm, which decomposes the problems into master and various slave problems. Large buses, i.e., up to 2383 bus systems, are used as a test system, and the results reveal that the proposed approach is fast and accurate.

D. Transmission Expansion for the European Northern Seas Offshore Grid using Novel Simulation Model

Dedecca *et al.,* [17] used the novel simulation models to analyze transmission expansion pathways of developing European Northern Seas offshore grid with several typologies. This simulation model demonstrated the effects of path dependence on grid expansion. In this wake, the research explains this concept in a better way than prior researches. It emphasizes myopic/short-sighted/single-period optimization in TEP. It also considered the impact of the pathway and its dependence on the grid path. The article discussed the lack of efficiency of a proper framework for the transmission and neglecting the HVDC innovation's impact on the grid expansion. The simulation model indicated the significance of taking into account diverse expansion plans with various typologies. The author also studies the Northern seas offshore grid development of the power transmitted through the ENTSO-E (European Network of Transmission System Operators for Electricity) with several topologies & factors.

E. Robust Transmission Expansion Planning Considering Long- and Short-term Uncertainty using Primal Benders' Decomposition Algorithm

Zhang *et al.,* [18] addressed the long term and short term uncertainty in transmission expansion planning. The uncertainty in growth and generation that deals with changes in years are term as long-term uncertainty. On the other hand, uncertainty considered within the span of one year is called short-term uncertainty. It is associated with changes that occur in the generation system, especially renewable resources. In this article, the primal Benders' decomposition problem algorithm is recommended for better optimization of the uncertainty of the system. This model has IEEE 118 bus case study that confirms its satisfactory response for a long-term plan with better understanding and protection against long-term uncertainty. Furthermore, it used the k-mean clustering technique to handle short-term uncertainty problems & issues.

F. Large-Scale Transmission Expansion Planning employing Progressive Heading and Benders Decomposition Algorithm

Majidi Qadikolai *et al.,* [19] deal with the planning of large-scale transmission network by its framework decomposition. The Progressive Heading (PH) and Benders Decomposition (BD) algorithms are used to propose the framework of the transmission network in this article. The gathered data are classified, clustered, grouped, and their bundles are created. This methodology improves the result with a decrease in computational time; thus, this model applies to a large system with 3179 buses and 4458 branches with 10 scenarios. This framework shows an excellent result in terms of higher quality and less computational time.

G. Co-optimization of Transmission Expansion Planning and TCSC placement considering the correlation between wind and demand scenarios

Ziaee *et al.,* [20] focused on this work about troubleshooting the issue of transmission expansion planning (TEP) with Thyristor Controlled Series Compensator (TCSC). It coalesces the TEP problem with the appropriate location of the TCSC issue in the transmission network. An optimization model comprising TCSC-assisted TEP is proposed that extracts the advantages of both planning problems. The proposed model counts on the DC approximation of the power flow network and links the length of the T/Line with its maximum power flow limit. The nonlinearity of the suggested model is evaded by employing two mixed-integer linear programs (MILP1 and MILP2) to achieve the effective solution of the given problem. The model proposed objective function diminishes the investment budgets and the anticipated generation and load shedding costs. This method dealt with a mixed-integer nonlinear program and provided a better solution. Its work in the nonlinear domain shifts into two cases of the mixed-integer linear program (MILP). The final results are trail on IEEE 118 bus system and analyzed their combined result. This causes an effective reduction in cost that makes it beneficial for commercial use, especially wind energy.

H. Dynamics of Power-Transmission Capacity Expansion under regulated remuneration

Zambrano *et al.,* [21] studied the significance of well-timed transmission capacity enhancement & expansion to secure power supply. Its planning can be centralized or decentralized,with each having its relevant pros and cons. This article analyses the centralized planning of transmission with auction competition, market-goaded decentralized planning, and hybrid planning coalescing features to obtain a better choice for investment in the transmission sector. This paper uses behavioral simulations, also known as system dynamics, and using it, a model of conventional system dynamics is established. For making decisions about investment in transmission capacity, this model obtains the important current conditions depending on the market incentives. The analysis is focused on the investment decision in a market with governed remuneration. The suggested model is validated for the Colombian Energy Market, and capacity development is simulated for various supervisory and demand situations. The paper concluded the prospective benefits by carrying out a TCE approach that cartels initiative from companies with indicators from the regulators. It is also emphasized to improve the information accessibility to prospective investors and planners, reducing planning delays, improving investment coordination, and curbing over-investment. This system shows the present conditions according to market incentives. In a nutshell, this paper emphasizesthe investment option in the market that generates better revenue.

I. A Hybrid Bat-Inspired Algorithm for Power Transmission Expansion Planning on a Practical Brazilian Network

C.A Moraes et al. [22]presented an adapted bat-inspired algorithm (ABA),a meta-heuristic approach using Enhanced Hybrid Algorithm (EHA), for TEP. The approach wields the discrete variables of TEP for the South Brazilian network and considers the losses of transmission.The algorithm has been inspired bythe echo sounding of micro-bats and employs sonar echoes to perceive and evade hindrances. The audio/sound pulses are converted into a frequency that echoes from the hindrances. The EHA pre-improves the method's effectiveness by attenuating the search space emplacing two indexes of sensitivity using Lagrange multipliers. The method proved to be effective forthe south Brazilian network,which contains numerous isolated buses.

J. Transmission Expansion Planning via Power Flow Controlling Technologies

Franken *et al.,* [23] studied the TEP for a system that considers the AC system and controlling technologies that improve the power flow. These technologies include HVDC, various FACTS devices and Phase Shifting Transformers (PST), etc. The study employs a Mixed Integer Programming approach to formulate and solve the model and found endogenous locations/operating points of power flowcontrol devices. The model helped to deduce that these controlling devices minimize the expansion costs.

K. Multi-Stage Dynamic Transmission Network Expansion Planning Using LSHADE-SPACMA

Refaat *et al.,* [24] studied a multi-staged TEP model taking into account the N-1 reliability limitations. West Delta Network of Egypt is considered for creating various scenarios for the study.The load forecasting (up to 2040) was achievedusing an adaptive neuro-fuzzy inference system as it results in incomparably good results to other conventional methods. The complex problem has been solved by the linear population size diminution-Success-History-based Differential Evolution with Semi-Parameter Adaptation (LSHADE-SPA) hybrid-covariance matrix adaptation evolution strategy (CMA-ES)algorithm (LSHADE-SPACMA). The advantage of employing LSHADE SPACMA in problem-solvinghas been recognized by comparing with other approaches. The said method proved to be optimum for both large and small-scale systems under-considered scenarios.

IV. COST ESTIMATION AND INVESTMENT EVALUATION PARAMETERS FOR TRANSMISSION SYSTEM EXPANSION

The sum that spends on the grid expansion plan needs prior cost estimation for the development and operation to assess the finances requirements and investment analysis for examining the economic viability at a glance. This section is divided into two parts;the first section outlines the cost estimation, and the second section elucidates investment evaluation.

A. Cost estimation

Each expansion plan or project is divided into different components for the grid stations and transmission lines, further divided into subcomponents. For the cost estimation purpose, it is required to identify each subcomponent broadly; however, the detailed list helps make cost estimation precisely. The cost estimation guides the present capital cost at which the required grid system will be constructed and elaborates the future operation and maintenance cost [25]. The components included in the cost estimation have been categorized into two portions: capital cost called CAPEX and operation cost OPEX, as depicted in Table 1.

Table 1: Cost estimation components.

Capital Cost (CAPEX)	Operation Cost (OPEX)
• Material	• Employees Cost
• Erection and installation	• Maintenance Cost
• Land	• Stores and spares
• Civil works	• Office expenses
• Interest during construction (IDC)	• Miscellaneous expenses
• Taxation during construction	
• Miscellaneous expenses	
• Contingencies (a percentage to total project cost to meet with unforeseen events)	

A. Investment Evaluation

The investment evaluation is the most vital stage of any plan or project to scrutinize the economic viability. The cost estimation discussed in the preceding section provides the base for the initial investment in the project [26]. There are various parameters, as shown in Table 2.

The above techniques are based on different variables, and the common variable among all is the discount factor, the life of the project, and cost estimation. Therefore, it is necessary to develop scenarios such as pessimistic, optimistic, and most likely. This provides a glance atthe whole expansion plan, either in total or for the individual scheme.

While making the transmission expansion plan, it essential to make an investment appraisal by applying the techniques mentioned above, and selection may be made for the most financially viable projects subject to any external factors, for instance, government policies. An important consideration in the expansion plan that it should also state the transmission and distributed plan separately to make cost computations and appraisal separately. Similarly, the off-grid and on-grid proposals are also required to be evaluated according to policies and technical requirements [27].

Generally, a two-step process is followed to consider the projects;the financial evaluation is made following the technical proposals. However, considering the expansion plan projects, a combined scoring system may be devised wherein the scores or weightage is assigned for technical and financial evaluation. The most scoring proposal ranked on top and considered for the implementation. However, it is also possible to consider a financially unviable project due to technical reasonability.The assigning weight is discretionary on the organization or the regulating agency whether to give more weightage to financial or technical terms [28].

Table 2: Investment evaluation parameters.

Parameters	Explanation	Formula
Net Present Value (NPV)	It represents the sum of discounted future cash inflowsand outflowsagainst the project. It is calculatedthrough the weighted average cost of capital (WACC). A project with a positive NPV is acceptable.	NPV = Present value of future revenue streams over the life of the project – Initial capital cost
Internal Rate of Return (IRR)	It is a discounting rate that equates the discounted future cash flow with the initial investment, and alternatively can say neither loss nor profit at this rate and NPV will be zero. It is calculated by trial & error method.	$IRR = r_a + \frac{NPV_a}{NPV_a - NPV_b}(r_b - r_a)$ r_a = lower discount rate chosen r_b = higher discount rate chosen NPV_a = NPV at r_a NPV_b = NPV at r_b
Payback Period	It particularizes the project period to cover the initial investment by generating sufficient cashflows.	Payback Period = Initial Investment / Revenue Stream (per year)
Discounted Payback Period	It is similar to the Payback Period method. The only difference is that the payback period is computed based on discounted future cash-flows instead of only future cash-flows.	Discounted Payback Period = Initial Investment / Discounted Revenue Stream (per year)
Profitability Index (PI)	It defines the earning per dollar of the investment. The sum of the present value of future cash flows isdivided bythe initial outflow gives the profitability index (PI) of the project.	PI = Present value of future cash flows / Initial investment
Accounting Rate of Return (ARR)	Indicates investments estimatedprofit as net accounting profit,also called return on investment (ROI).	ARR=(Average annual profit after tax / Initial investment) X 100

V. CONCLUSION

This paper highlights the importance of and need for Transmission Expansion Planning (TEP) in terms of various investigations. Researchers' methods/techniques have been studied to identify the factors to consider when planning the expansion of power transmission. In the light of these expansion plans, the transmission system operators need to update their short and long-term plans based on modern research. The most feasible and advantageous expansion method and the algorithm used depends on the application and challenges posed to that particular transmission network. The optimal approach must address the expansion planning as a complex problem capturing all random and non-random uncertainties. Owing to its simpleness, practicality, local optima restraint, flexibility, and applicability to large-scale systems, etc., meta-heuristic approaches are preferred over mathematical optimization and heuristic approaches for most of the modern complex transmission systems. Meta-heuristicapproaches improve the solution with successive iteration, abstracting stimulus from natural processes. The cost estimation and investment evaluation parameters identified in this research are extremely vital and must be studied before implementing the transmission expansion plan. With the useof these modern methods, the transmission system can be expanded with greater efficiency, less cost, and more control over the system can be attained with less efforts involved.

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