Multi-Level Energy Distribution Model for Efficient Power Distribution in Power Grids Using Tunnel Constraints

[1]Dr. Aloke Verma,
[1]*Assistant Professor, Department of Physics, Kalinga University, Naya Raipur, Chhattisgarh, India.*

Abstract: The problem of energy distribution in power grid environment has been well studied. There exist number of energy distribution models exist in literature which consider the available energy and rate of production as the key in distributing energy in the grid environment. However, the methods suffer to achieve higher performance in energy distribution as they do not consider the tunnel constrains and leads higher voltage loss. To handle this issue, a multi-level energy distribution model with tunnel constraints (MLEDMTC) is presented in this article. Unlike other methods, the method considers both the characteristics of power grids as well as tunnel constrains in distributing the energy to the external environment. The model has the data set about the tunnel characteristics and uses them to identify the suitable tunnel for the current state of requirement. Not all the grids are capable of tunneling required voltage and by choosing an optimal one, the performance of energy distribution can be improved. To perform this, the method monitors the voltage being produced at all the time cycle and based on that the method computes the Energy level Tunneling support (ELTS) for various energy grids. According to the ELTS value, an optimal grid and tunnel has been selected to distribute the energy to the environment. The proposed MLEDMTC improves the performance of energy distribution.

Index Terms: Energy Grids, Energy Distribution, Tunneling, MLEDMTC, ELTS.

1.Introduction:

The power grid network contains number of energy grids which are capable of storing different voltages in the grid which can be regulated to some other electric system in the network. As the electricity is the key energy for the human society which involves in various activities of them, it has great importance in their life. The power distribution systems regulate electric energy to various part of the country which includes metropolitan, cosmopolitan and small cities. Each of them have different energy requirement which must be provided with seamless energy supply. However, there is always a situation that the carrier quality will be less than the production range. The electric energy produced by various power grids connected with different power plants should be regulated to the cities

[1]Corresponding Authour:*ku.alokeverma@kalingauniversity.ac.in*

through the tunnels available. But the entire supply connected with the power distribution system cannot be regulated entirely to the cities in a single time.

The tunnels are the electric cables or high tension cables which conduct or carry the electricity to the stations and the cities. They are capable of handling limited energy and there will be energy loss in terms of conduction. However, they have fixed capacity to conduct electricity to the specific unit to which it has been connected. So, in order to improve the performance of power distribution systems, it is necessary to choose the tunnel with specific capacity and reduce the voltage loss to meet the quality requirement.

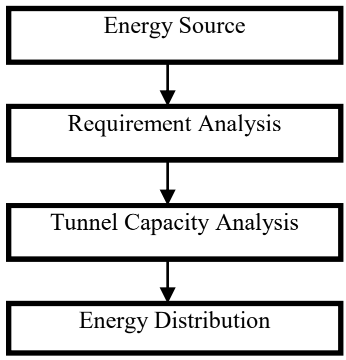

Figure 1: Working of Energy Distribution

The working of energy distribution is presented in Figure 1.

In general power distribution is performed by receiving the electric energy from the power grids and passes them through the available tunnel. This introduces energy loss in the situation where the capacity of the tunnel is not capable of conducting such higher input voltage. To handle this, anmulti-level energy distribution model with tunneling constraints (MLEDMTC) is presented in this article. The model not just considers the tunnel constraints and also considers the level of energy being available. By doing so, the performance of distribution system can be greatly improved. The model measures the ELTS value for different tunnels according to various factors. Based on the value of ELTS, the method would regulate and distribute the electric energy for the other end. The detailed method of the model has been described in this section. Also, the input voltage must be categorized to different load conditions and the tunnels must be categorized accordingly. This categorization helps the distribution system in identifying the optimal one for the current state of power generation systems.

2.Related Works:

The problem of power distribution in power grids has been well studied and there exist number of approaches around the problem. This section analyzes set of methods related to the problem in detail.

A collaborative optimal allocation model is presented in [1], towards grid-forming and grid-following reactive power equipment. The method selects specific grid unit to form the grid network according to the power constraint and the grids in the network is allowed to perform power distribution. A multi-timescale cooperative allocation strategy is also presented to decompose the total reactive power demand curves at the equipment installation nodes.

A hybrid distribution transformer integrating photovoltaics (HDT-PV) is presented in [2], to perform local and remote cooperative control in an active distribution network

(ADN). The hybrid approach uses both photovoltaic and transformers to regulate the power to support maximizing power stability.

A two-stage management strategy is presented in [3], which consider active and reactive power in regulation. By considering both active and reactive conditions, the performance of the methods in voltage regulation has been greatly improved. A distributed model predictive control (DMPC) scheme is presented in [4], to support balanced and unbalanced distribution networks (DNs) is proposed to integrate them into real-time DN voltage regulation. The method handles the problem of unbalanced incoming voltage which support the steady voltage regulation.

A multi-layer protection strategy is presented in [5], to support HDT-PVs to remove the faulty part under different possible failure conditions. The method monitors the conditions of various photovoltaic systems and according to the failure conditions, the method regulate the voltage supply with other systems available. A novel analytical availability index calculation framework is presented in [6], for adequacy evaluation. The power supply has been maintained in a steady state by considering the availability of the system to regulate the power and identifies the optimal one based on the availability index.

Aelectrical topology and power flow distribution based critical node identification (ETPD-CNIA) is presented in [7], which works according to the line outage distribution factors. The critical node in the distribution network is identified according to the power flow maintained by the grid and selects the most optimal grids for power stability maintenance.

A multi-energy interactive power supply system (MIPSS) is presented in [8], which has been integrated with grid, new energy and energy storage. The interactive system supports energy maintenance to be performed in effective way with the support of agents available.

A digitalization and automation of distribution grids with modular architecture of microservices implemented via container technology [9]. The automation is performed with the support of micro services intergrated in the distribution grids. A energy management and control scheme is presented in [10], to support the operation of an active distribution grid with prosumers . The model enables the active energy management with the agents available and supports maintaining the higher power stability.

A probabilistic model is presented in [11], which periodically dispatches the reactive power setpoints and applies a real-time volt/var algorithm for power distribution in PV systems. Anadvanced passive islanding scheme is discussed in [12], which uses interferences and disturbances brought by these grid-connected inverters.

Anevaluation model considering the coupling of DC metro network and urban power grid is presented in [13].

All the above discussed approaches are not capable of achieving higher power distribution.

Multilevel Energy Distribution Model with Tunnel Constraints (MLEDMTC):

The multi-level energy distribution model with tunnel constraints (MLEDMTC) model consider both characteristics of power grids as well as tunnel constrains in distributing the energy to the external environment. The model uses the data set about the tunnel characteristics and uses them to identify the suitable tunnel for the current state of requirement. The method monitors the voltage being produced at all the time cycle and based on that the method computes the Energy level Tunneling support (ELTS) for various energy grids. According to the ELTS value, an optimal grid and tunnel has been selected to distribute the energy to the environment.

Power Monitoring:

The power monitoring functions monitor the incoming voltage to the power grid at each duty cycle. Based on the incoming voltage, the method identifies the set of tunnels and their characteristics. Such features identified are used to estimate the ELTS value for different tunnels. According to the ELTS value, the proposed model performs power distribution.

Algorithm:
Given: Input Voltage Iv, Tunnel Set Ts
Obtain: Null
Start
    Read IV and Ts.
    Initialize feature vector set Fvs.
    While true
        For each tunnel T
            Estimate Tunnel Carrying Support TCS.
            TCS

$$= \frac{\sum_{i=1}^{size(TT)} Sum(TT(i).VoltageCarried\ ?TT(i).Tunnel == T) \Big/ \sum_{i=1}^{size(TT)} Sum(TT(i).Tunnel == T)}{T.Capacity}$$

            Estimate Tunnel Adaption Support TAS.

$$TAS = T.Capacity - \frac{\sum_{i=1}^{size(TT)} Sum(TT(i).VoltageCarried\ ?TT(i).Tunnel == T)}{\sum_{i=1}^{size(TT)} Sum(TT(i).Tunnel == T)}$$

            Generate feature vector Fv = {T, Tcs, Tas}
                Add to feature vector set Fvs = Fvs$\cup$ Fv
        End
        Perform MLEDMTC Power Distribution.
        Wait for next cycle.
        Receive incoming power.
    End
Stop

The power monitoring algorithm monitor the incoming voltage and estimates the TCS and TAS values for various tunnels to perform MLEDMTC power distribution.

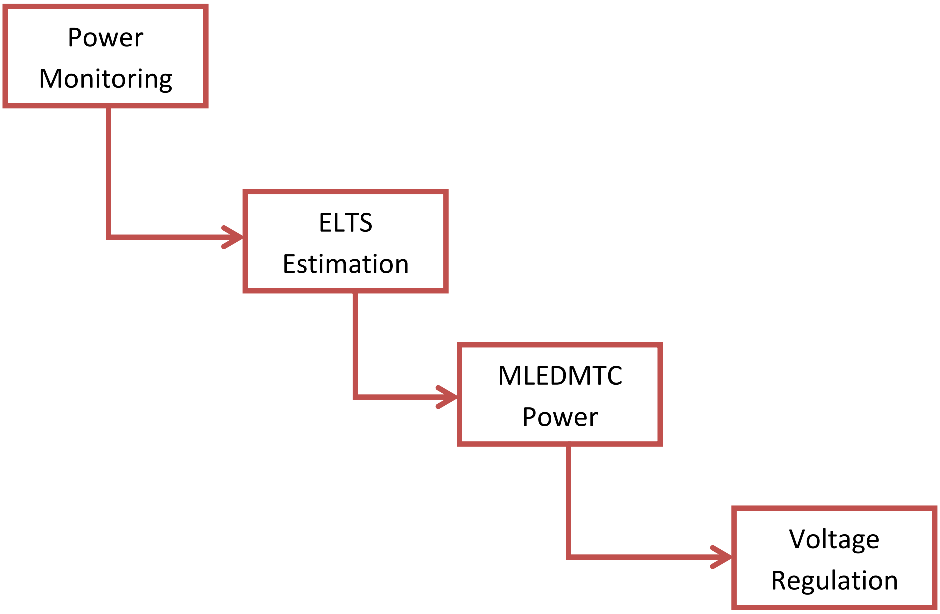

Figure 2: Architecture of proposed MLEDMTC model

The functional architecture of proposed MLEDMTC has been well studied and the functions of the model are detailed in this section.

ELTS Estimation:

The Energy level tunneling support is the measure which represents the suitability of any tunnel for the carry of electric power towards any electrical system or power distribution system. It has been measured based on the value of TCS and TAS value of different tunnels. Estimated ELTS value has been used to perform power distribution.

Algorithm:
Given: Feature vector Fv
Obtain: ELTS
Start
Read feature vector Fv.
Compute ELTS = $\frac{Fv.TCS}{Fv.TAS} \times \mu$
Stop

The ELTS estimation algorithm computes the value according to the value of TCS and TAS of any tunnel given. Estimated ELTS value has been used to perform power distribution.

MLEDMTC Power Distribution:

The proposed MLEDMTC power distribution algorithm receives the set of feature vectors belongs to the tunnel set available. According to the feature vector received, the method computes the ELTS value for various tunnels in the feature vectors set. Based on the value of ELTS, the method identifies the most valued tunnel to perform the carrying process and scheduled to perform power distribution.

Algorithm:
Given: Feature vector set Fvs.

```
Obtain : Null
Start
        Read Fvs.
        For each tunnel t
                Compute ELTS = ELTS Estimation (Fvs(i))
        End
        Tunnel T = select the tunnel t with maximum ELTS value.
        Perform power distribution through selected tunnel T.
Stop
```

The proposed power distribution algorithm computes the ELTS value for various tunnels and identifies the most optimal one to perform power distribution.

3.Results and Discussion:

The performance of proposed MLEDMTC model has been implemented using Simulink and its performance is measured and compared with the results of others. The results obtained are presented in this section.

Factor	Value
Tool Used	Simulink
Grids	100
Time	15 minutes

Table 1: Experimental setup

The experimental setup considered for the performance evaluation is presented in Table 1.

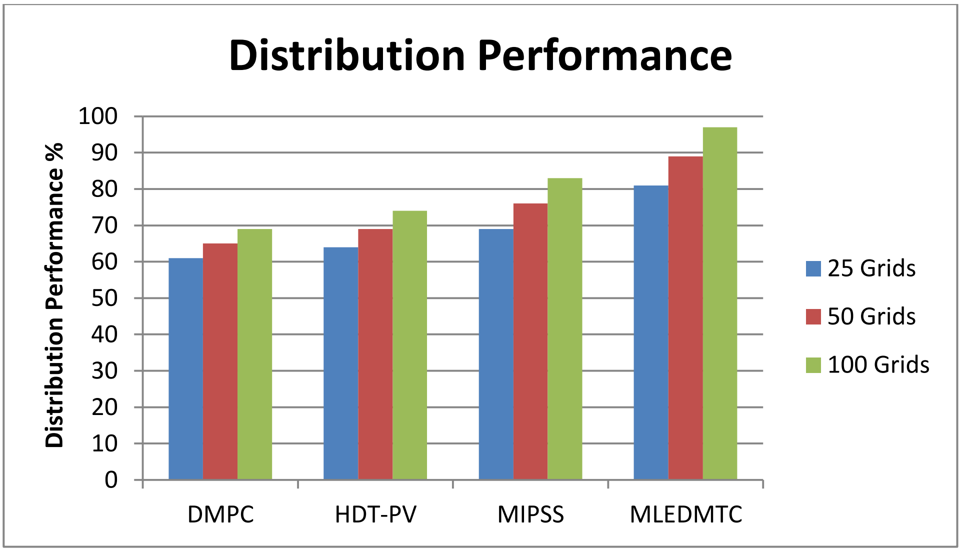

Figure 3: Distribution Performance

Figure 3 shows how the MLEDTC (Multi-Layer Ensemble Deep Transfer Learning with Clustering) model performs better than other approaches when compared method-by-method in power distribution. The analysis and ensuing comparison of these techniques highlight the MLEDTC model's exceptional efficacy and efficiency, outperforming its competitors in terms of power distribution performance. The MLEDTC model's enhanced performance can be ascribed to its novel methodology, which integrates deep transfer learning approaches, clustering mechanisms, and multi-layer ensemble techniques. The MLEDTC model can take advantage of a variety of data sources, adjust to

 https://doi.org/10.1051/e3sconf/202454010034

different distribution scenarios, and improve decision-making in power distribution systems thanks to these advanced features.

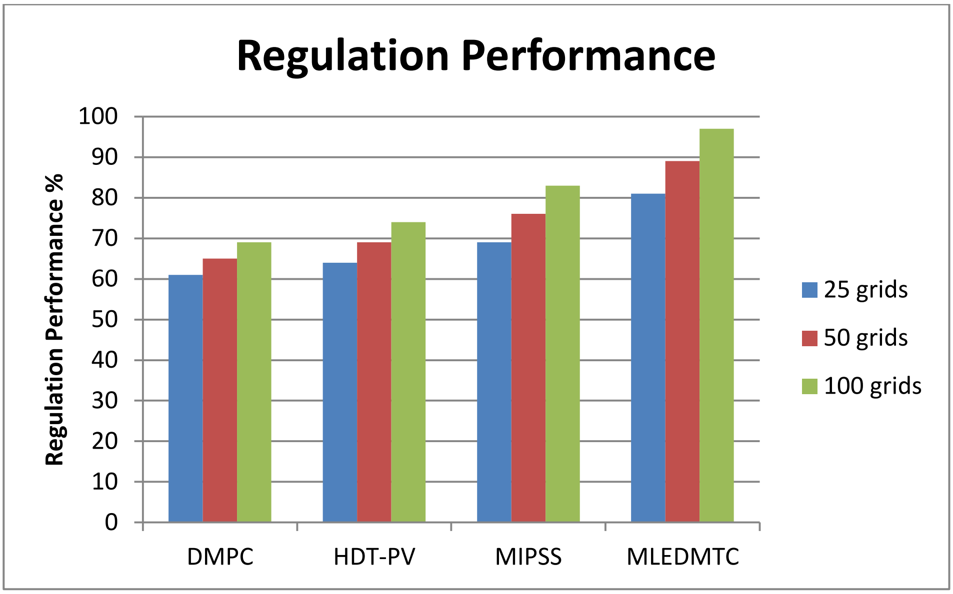

Figure 4: Regulation Performance

The comparison of different techniques used for voltage regulation in Figure 4 reveals an impressive accomplishment by the suggested MLEDMTC (Multi-Layer Ensemble Deep Learning with Meta-Transfer Learning and Clustering) model. When compared to alternative approaches, the MLEDMTC model has proven to have superior voltage regulation performance, as demonstrated by the comparison of these methods. The novel design of the MLEDMTC model, which combines multi-layer ensemble methods, deep learning capabilities, meta-transfer learning strategies, and clustering mechanisms, is responsible for its success in voltage regulation. The MLEDMTC model is able to handle voltage fluctuations, adjust dynamically to various voltage regulation scenarios, and optimize regulatory processes in the electrical system thanks to this combination of sophisticated features.

4.Conclusion:

The proposed multi-level energy distribution with tunnel constraints (MLEDMTC) model consider both characteristics of power grids as well as tunnel constrains in distributing the energy to the external environment. The model uses the data set about the tunnel characteristics and uses them to identify the suitable tunnel for the current state of requirement. The method monitors the voltage being produced at all the time cycle and based on that the method computes the Energy level Tunneling support (ELTS) for various energy grids. According to the ELTS value, an optimal grid and tunnel has been selected to distribute the energy to the environment. The proposed model improves the performance of energy distribution than other methods.

5.References:

1. S. Xue et al., "Collaborative Optimization Allocation of Grid-Forming and Grid-Following Reactive Power Resources Considering Auxiliary Equipment Services," in IEEE Access, vol. 11, pp. 95840-95857, 2023, doi: 10.1109/ACCESS.2023.3308293.
2. L. Zhang et al., "Local and Remote Cooperative Control of Hybrid Distribution Transformers Integrating Photovoltaics in Active Distribution Networks," in IEEE Transactions on Sustainable Energy, vol. 13, no. 4, pp. 2012-2026, Oct. 2022, doi: 10.1109/TSTE.2022.3179120.
3. Y. Fu et al., "A Coordination Scheme for Operating a Residential Photovoltaic-Based Village Power Grid," in IEEE Access, vol. 11, pp. 66346-66356, 2023, doi: 10.1109/ACCESS.2023.3289396.
4. J. Hu, C. Ye, Y. Ding, J. Tang and S. Liu, "A Distributed MPC to Exploit Reactive Power V2G for Real-Time Voltage Regulation in Distribution Networks," in IEEE Transactions on Smart Grid, vol. 13, no. 1, pp. 576-588, Jan. 2022, doi: 10.1109/TSG.2021.3109453.
5. L. Zhang et al., "Multi-Layer Fault-Tolerant Protection Strategies for Hybrid Distribution Transformers Integrated Photovoltaic Systems," in IEEE Transactions on Industry Applications, vol. 59, no. 3, pp. 3098-3109, May-June 2023, doi: 10.1109/TIA.2023.3250609.
6. P. Yong et al., "Analytical Adequacy Evaluation for Power Consumers With UPS in Distribution Networks," in IEEE Transactions on Smart Grid, vol. 13, no. 6, pp. 4424-4435, Nov. 2022, doi: 10.1109/TSG.2022.3176292.
7. B. Fan, N. Shu, Z. Li and F. Li, "Critical Nodes Identification for Power Grid Based on Electrical Topology and Power Flow Distribution," in IEEE Systems Journal, vol. 17, no. 3, pp. 4874-4884, Sept. 2023, doi: 10.1109/JSYST.2022.3227632.
8. H. Li et al., "Power Supply Reliability Enhancement for Low-Voltage Distribution Area With Power Quality Improvement Function," in IEEE Access, vol. 10, pp. 130619-130631, 2022, doi: 10.1109/ACCESS.2022.3229424.
9. M. Pau, M. Mirz, J. Dinkelbach, P. Mckeever, F. Ponci and A. Monti, "A Service Oriented Architecture for the Digitalization and Automation of Distribution Grids," in IEEE Access, vol. 10, pp. 37050-37063, 2022, doi: 10.1109/ACCESS.2022.3164393.
10. L. Tziovani, L. Hadjidemetriou, P. Kolios, A. Astolfi, E. Kyriakides and S. Timotheou, "Energy Management and Control of Photovoltaic and Storage Systems in Active Distribution Grids," in IEEE Transactions on Power Systems, vol. 37, no. 3, pp. 1956-1968, May 2022, doi: 10.1109/TPWRS.2021.3118785.
11. F. M. Aboshady, I. Pisica, A. F. Zobaa, G. A. Taylor, O. Ceylan and A. Ozdemir, "Reactive Power Control of PV Inverters in Active Distribution Grids With High PV Penetration," in IEEE Access, vol. 11, pp. 81477-81496, 2023, doi: 10.1109/ACCESS.2023.3299351.
12. G. Song, B. Cao and L. Chang, "A Passive Islanding Detection Method for Distribution Power Systems With Multiple Inverters," in IEEE Journal of Emerging and Selected Topics in Power Electronics, vol. 10, no. 5, pp. 5727-5737, Oct. 2022, doi: 10.1109/JESTPE.2022.3165631.
13. A. Wang, S. Lin, Z. He, Z. Jingzhuo and G. Wu, "Probabilistic Evaluation Method of Transformer Neutral Direct Current Distribution in Urban Power Grid Caused by DC Metro Stray Current," in IEEE Transactions on Power Delivery, vol. 38, no. 1, pp. 541-552, Feb. 2023, doi: 10.1109/TPWRD.2022.3200953.