Spectrum of Engineering Sciences
ISSN (E): 3006-7030 ISSN (P) : 3006-7022 Volume 3, Issue 4, 2025

SIMULATION-BASED CONDUCTOR OPTIMIZATION FOR POWER DISTRIBUTION FEEDERS, A COMPARATIVE STUDY USING ETAP

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DOI: https://doi.org/10.5281/zenodo.15221453

Keywords
Energy loss reduction; Voltage profile; Reactive power; Distribution feeder; Power flow analysis; Power loss reduction; power system

Article History
Received on 28 February 2025
Accepted on 28 March 2025
Published on 15 April 2025

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Abstract

The electrical distribution system is the final and most crucial stage in the power grid, responsible for delivering electric power to consumers. As distribution networks are located close to end users, it becomes essential to thoroughly plan and manage the system to minimize power losses and ensure that voltage levels remain within acceptable limits for reliable operation. A significant aspect of such planning involves selecting the optimal conductors for each section of the distribution feeder, as the choice of conductor directly influences the system's efficiency and performance. This paper focuses on the practical planning of a distribution system by selecting the optimal conductors for an 11 kV distribution feeder, aiming to minimize power losses and enhance voltage levels. A novel approach is proposed for optimal conductor selection in radial distribution networks, utilizing power flow studies in the Electrical Transient Analyzer Program (ETAP). The methodology involves comparing the results of different conductor configurations while considering the increasing load demands over time. Several objective functions are incorporated into the model, such as maintaining voltage limits, ensuring adequate current-carrying capacity, selecting the appropriate conductor sizes and types, minimizing power loss costs, and improving the overall voltage profile. The findings demonstrate that reducing energy losses within the distribution system conserves available system capacity, eliminating the need for additional capacity installation. This approach also yields improved system stability, a more optimal voltage profile, and a decrease in both active and reactive power losses. Furthermore, the system's energy handling capacity is enhanced while maintaining minimal costs. This method offers a comprehensive solution for optimizing the distribution system, ensuring improved performance and efficiency while minimizing operational costs and enhancing the system's overall reliability.

INTRODUCTION

Power losses are invariably associated with electric power transmission from generating stations to consumers. These losses, which are inherent in power systems, can be broadly categorized into transmission losses and distribution losses. Among these, distribution losses are particularly significant, accounting for nearly 70% of the total system losses and playing a substantial role in system inefficiency. Given their substantial impact, addressing these losses is crucial for improving overall power system performance. A primary cause of distribution losses is the Joule effect, which can account for up to 13% of the total generated power [1, 2]. Such losses not only reduce system efficiency but also have severe economic implications, particularly in developing countries where power infrastructure is already strained [1]. For instance, in Pakistan, transmission and distribution losses amount to approximately 19.6% of the total generated electricity, with 2.48% occurring during transmission and a staggering 17.54% during distribution [3].

Distribution losses can be further classified into technical losses and non-technical losses. Technical losses occur due to factors such as conductor resistance, which leads to heat dissipation, reactance, load characteristics, and power flow dynamics. Common examples include losses in distribution lines and transformers, which can be accurately modeled and quantified. On the other hand, non-technical losses stem from issues such as illegal connections, meter tampering, billing errors, and inefficient energy management practices [2]. These losses are more challenging to measure and control, often requiring policy interventions and improved monitoring systems.

The optimal planning of electric distribution systems is a critical area of research, given the increasing focus on minimizing system losses. While numerous studies have explored strategies for loss reduction and cost optimization, one key aspect that remains understudied is the selection of optimal conductor sizes [4-8]. Many existing approaches focus on minimizing costs by improving conductor profiles and reducing loss-related expenses. However, most of these studies fail to account for future load growth, which is essential for long-term system sustainability. Additionally, the primary objective of an Electrical Distribution System (EDS)—to deliver cost-effective and reliable power to consumers—is often overlooked. Therefore, a comprehensive planning approach must consider multiple factors, including equipment utilization rates, installation costs, service quality, loss reduction, and system reliability, while also accounting for projected load increases [9].

When modeling Conductor Size Selection (CSS) problems, several key parameters must be considered, including the economic lifespan of conductors, installation costs, discount rates, and circuit types. Some studies have employed dynamic programming to address CSS challenges [9], while others have proposed techno-economic optimization methods for radial distribution networks. These methods assess load growth patterns and network constraints to determine the optimal timing for conductor replacements, ensuring both technical efficiency and cost minimization [5].

Several techniques have been explored for conductor selection, including heuristic methods, sensitivity indices, and linear approximation models. For instance, one study introduces a sensitivity index-based approach for reactive power injection to enhance EDS performance [9]. While heuristic methods are robust and easy to implement, they often converge to local optima rather than global solutions. Other studies utilize linear approximations for loss and voltage regulation calculations [11], whereas some models feature constant current sources. Additionally, mixed-integer linear programming (MILP) has been applied to CSS problems, offering a structured optimization framework [11].

Evolutionary algorithms, such as the Genetic Algorithm (GA), have also been employed for optimal conductor selection in radial distribution systems. These methods aim to minimize annual energy loss costs and conductor expenses while improving system efficiency. The Backward-Forward Sweep (BFS) method is commonly used to compute key parameters, such as voltage magnitude, power losses, and current flows. Comparative studies have shown that GA outperforms conventional techniques in loss reduction and voltage profile enhancement, resulting in improved economic and operational outcomes [12]. Another innovative approach involves the Bacterial Foraging Algorithm (BFA), which has been compared with the Imperialist Competitive Algorithm (ICA) for conductor selection. The objective is to reduce annual energy loss costs and conductor prices while ensuring compliance with current-carrying capacity limits and voltage standards [13]. This paper presents a practical approach to distribution system planning by focusing on optimal conductor selection in radial networks. The goal is to minimize power losses and enhance voltage stability across all feeder buses. A novel methodology is introduced, comparing different conductor types through power flow analysis in ETAP (Electrical Transient Analyzer Program) while considering load growth trends. The study involves designing distribution feeders with various conductors and analyzing real and reactive power flows, current distribution, and losses. Based on these analyses, the most cost-effective conductors for different feeder sections are selected, factoring in both loss costs and conductor installation expenses.

ETAP is chosen for power flow simulations due to its advanced analytical capabilities, including:

- Automatic equipment evaluation
- Comprehensive alerts and warnings
- Detailed load flow result analysis
- User-friendly graphical interface

By leveraging ETAP's precision in power flow and voltage drop calculations, this study ensures accurate and reliable results, ultimately aiding in the development of efficient and economically viable distribution networks.

Power Flow Analysis

Power flow analysis is a numerical technique used to assess and evaluate the flow of electric power in interconnected electrical systems. The primary objective of this study is to identify system sensitivities concerning variations in power loading, conductor length, and transformer capacity at the distribution level. By conducting a power flow analysis, engineers can ensure the reliable, stable, and cost-effective delivery of electricity from generation sources to end consumers through transmission and distribution networks. One of the key goals of a load flow study is to verify that voltage levels at all busbars remain within permissible limits while ensuring that active and reactive power transfer is optimized to maintain high-quality service for consumers.

Load flow calculations are crucial for the design, planning, and operation of power systems, as they enable the analysis of the network's static performance under various operating conditions. These studies are typically conducted using specialized computer simulation software, which allows engineers to model complex power systems and accurately predict their behavior [14]. To overcome the computational challenges associated with traditional load flow solution methods—such as the Newton-Raphson and Gauss-Seidel iterative techniques [15]—the most effective approach is to develop a realistic simulation model. For accurate results, the model must be based on real-world operating conditions, incorporating actual system data to ensure that the simulation reflects proper performance [16]. By utilizing advanced software tools, engineers can monitor system behavior at each bus, identify potential weaknesses, and implement necessary design modifications to enhance overall efficiency [16].

In this study, the power flow analysis of a distribution feeder is conducted using ETAP software, examining different conductor types, including RABBIT, DOG, PANTHER, and OSPREY. The study aims to determine the optimal conductor configuration that minimizes losses and enhances voltage regulation, considering real-world load conditions. The results obtained from these simulations will help in selecting the most efficient conductors for various sections of the distribution network, ensuring both technical performance and economic feasibility.

Design of Distribution Feeder in ETAP

The single-line diagram of the feeder, designed and analyzed in the ETAP software, consists of a total of 32 sections, each with a length of 1000m, resulting in a total length of 32 km for the distribution lines. Distribution transformers connected to the feeder are 23, and the total load connected is 8,050 kVA.

ISSN (E): 3006-7030 ISSN (P) : 3006-7022 Volume 3, Issue 4, 2025

Fig. 1 illustrates the design and load flow study of an 11 kV distribution feeder in ETAP, which also displays the names assigned to the buses.

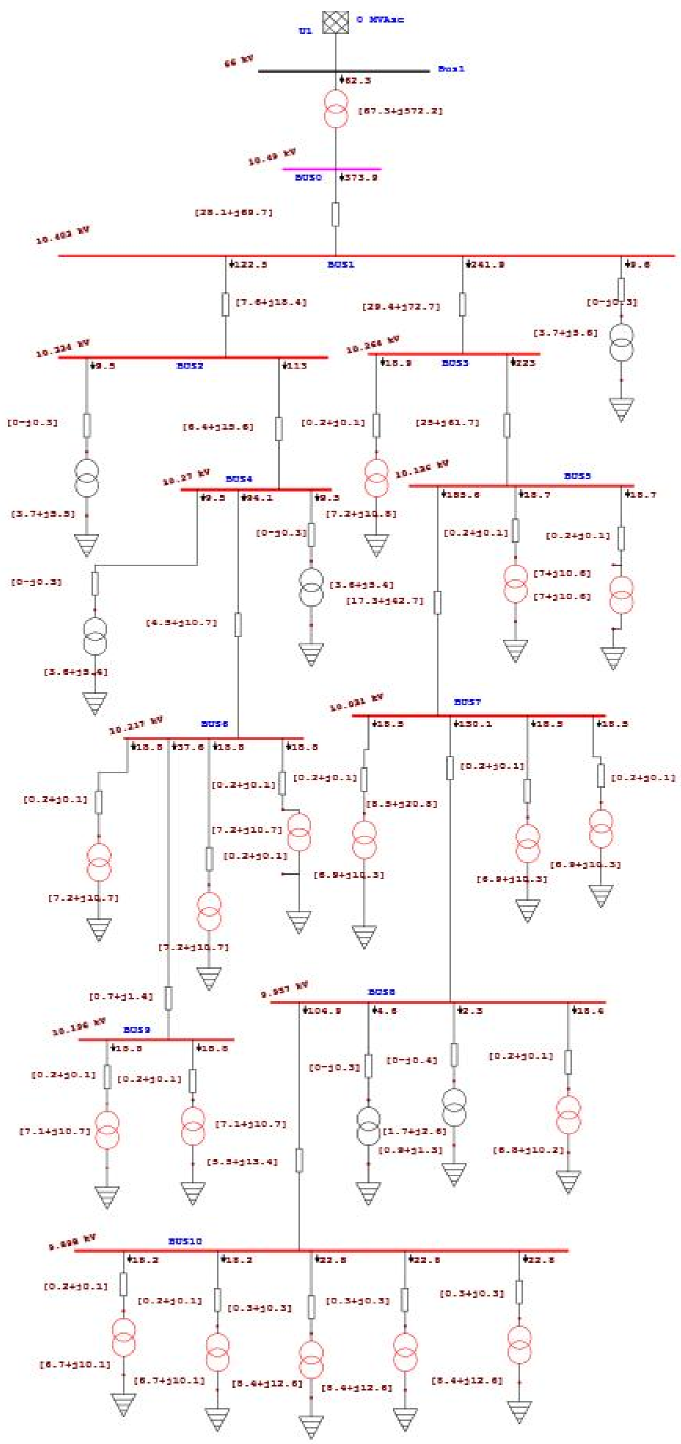

Fig. 1. Design and load flow study of an 11kV distribution feeder in ETAP

B. Analysis of Distribution Feeder Using ACSR (RABBIT) Conductor in Each Section of Feeder

After designing the distribution feeder in ETAP software with ACSR (RABBIT) conductors installed across all sections, a comprehensive analysis was performed. The study evaluated the voltage profile at each bus and quantified the power losses in every branch. The results obtained (illustrated in Fig. 2) demonstrate that branches supplying higher loads dissipate more power, leading to increased losses due to higher current flow.

The analysis revealed that the total power loss in the feeder amounts to 395.41 kW. When extrapolated over a year, this translates to an energy loss of 3,463,791.6 kWh, which incurs a financial loss of approximately 44,925,377.052 Pakistani Rupees (PKR). Such significant energy wastage highlights the urgent need for loss reduction strategies to improve system efficiency and economic viability. Additionally, the initial investment required for purchasing and installing the ACSR (RABBIT) conductors alone is estimated at 2,227,200 PKR. This substantial capital expenditure underscores the importance of selecting the optimal conductor to balance upfront costs with long-term savings from reduced losses.

TABLE I. VOLTAGE LEVEL AT EACH BUS AND LOADING OF EACH BUS WHEN RABBIT CONDUCTOR IS USED

Bus ID	Nominal kV	Voltage (kV)	MW Loading	MVAR Loading	Amp Loading
BUS0	11	10.523	5.88	2.809	357.5
BUS1	11	10.365	5.828	2.736	357.5
BUS2	11	10.23	1.923	0.879	119.4
BUS3	11	10.076	3.616	1.688	228.6
BUS4	11	10.076	1.747	0.793	109.9
BUS5	11	9.783	3.233	1.49	210.1
BUS6	11	9.949	1.435	0.648	91.38
BUS7	11	9.539	2.617	1.194	174.1
BUS8	11	9.37	1.794	0.814	121.4
BUS9	11	9.898	0.57	0.257	36.44
BUS10	11	9.234	1.424	0.643	97.7

TABLE II. LOSSES LINKED WITH AND AMPERE FLOWS IN EACH SEGMENT OF LINE WHEN RABBIT CONDUCTOR IS USED

Line Section	Current Flow (amperes)	Power Losses (kW)	Line Section	Current Flow (amperes)	Power Losses (kW)
Line1	119.3	28.784	Line18	18.31	0.677
Line2	109.9	24.423	Line19	18.31	0.126
Line3	228.6	107	Line20	17.56	0.116
Line5	210.1	90.619	Line21	17.56	0.116
Line6	91.37	16.871	Line22	17.56	0.116
Line7	174.1	62.446	Line23	18.22	0.67
Line8	121.4	32.36	Line24	18.22	0.67
Line9	36.43	2.68	Line25	4.322	0.039
Line10	97.7	19.811	Line26	2.162	0.01
Line11	9.578	0.185	Line27	17.25	0.618
Line12	9.424	0.179	Line28	17	0.6
Line13	9.283	0.174	Line29	17	0.6
Line14	9.283	0.032	Line30	21.24	0.936
Line15	18.01	0.654	Line31	21.24	0.936
Line16	18.31	0.677	Line33	21.24	0.936
Line17	18.01	0.654	Line35	18.55	0.695

Analysis of Distribution Feeder Using ACSR (DOG) Conductor in Each Section of Feeder

The analysis of the feeder, when designed with an ACSR (DOG) conductor, gives the voltage level at each bus as well as the losses associated with each branch. There are a total of 209.523 kW losses associated with this feeder. Approximately 1,835,421.48 kilowatt-hours of energy, which costs up to 23,805,416.60 Pakistani Rupees, are wasted due to annual losses. The investment of 4,454,400 Pakistani Rupees should be made for the first time to purchase only the conductors. Table III displays the voltage at each bus of the distribution feeder, as well as the MW, MVAR, and ampere loading of each bus in the feeder. Table IV describes the losses that are linked with each section of the line and the current that flows in each section.

TABLE III. Voltage Level At Each Bus And Loading Of Each Bus When Dog Conductor Is Used

Bus ID	Nominal kV	Voltage (kV)	MW Loading	MVAR Loading	Amp Loading
BUS0	11	10.502	5.984	2.94	366.5
BUS1	11	10.372	5.93	2.863	366.5
BUS2	11	10.265	1.953	0.901	121
BUS3	11	10.162	3.748	1.792	236
BUS4	11	10.167	1.787	0.815	111.5
BUS5	11	9.97	3.399	1.59	217.3
BUS6	11	10.086	1.477	0.668	92.8
BUS7	11	9.811	2.788	1.283	180.6
BUS8	11	9.7	1.932	0.881	126.4
BUS9	11	10.054	0.588	0.265	37.05
BUS10	11	9.611	1.544	0.697	101.8

TABLE IV. Losses Linked With And Ampere Flows In Each Segment Of Line When Dog Conductor Is Used

Line Section	Current Flow (amperes)	Power Losses (kW)	Line Section	Current Flow (amperes)	Power Losses (kW)
Line1	119.3	14.925	Line18	18.31	0.352
Line2	109.9	12.684	Line19	18.31	0.352
Line3	228.6	56.81	Line20	17.56	0.333
Line5	210.1	48.16	Line21	17.56	0.333
Line6	91.37	8.781	Line22	17.56	0.333
Line7	174.1	33.256	Line23	18.22	0.35
Line8	121.4	16.283	Line24	18.22	0.35
Line9	36.43	1.4	Line25	4.322	0.02
Line10	97.7	10.568	Line26	2.162	0.005
Line11	9.578	0.093	Line27	17.25	0.326
Line12	9.424	0.091	Line28	17	0.32
Line13	9.283	0.09	Line29	17	0.32
Line14	9.283	0.09	Line30	21.24	0.5
Line15	18.01	0.344	Line31	21.24	0.5
Line16	18.31	0.352	Line33	21.24	0.5
Line17	18.01	0.344	Line35	18.55	0.358

Analysis of Distribution Feeder Using ACSR (PANTHER) Conductor in Each Section of Feeder

The analysis of the feeder, when designed with an ACSR (PANTHER) conductor, gives the voltage level at each bus as well as the losses associated with each branch. There are a total of 108.422 kW losses related to this feeder. Approximately 949,776.72 kilowatt-hours of energy, which costs up to

12,318,604.0584 Pakistani Rupees, are wasted due to annual losses. The investment of 9,600,000 Pakistani Rupees should be made for the first time to purchase only the conductors. Table V displays the voltage at each bus of the distribution feeder, as well as the MW, MVAR, and ampere loading of each bus in the feeder. Table VI describes the losses that are linked with each section of the line and the current that flows in each section.

TABLE V. Voltage Level At Each Bus And Loading Of Each Bus When Panther Conductor Is Used

Bus ID	Nominal kV	Voltage (kV)	MW Loading	MVAR Loading	Amp Loading
BUS0	11	10.49	6.089	3.013	373.9
BUS1	11	10.403	6.061	2.944	374
BUS2	11	10.334	1.991	0.92	122.5
BUS3	11	10.264	3.876	1.862	241.9
BUS4	11	10.27	1.829	0.834	113
BUS5	11	10.136	3.544	1.662	223
BUS6	11	10.217	1.517	0.686	94.09
BUS7	11	10.031	2.929	1.349	185.6
BUS8	11	9.957	2.042	0.932	130.1
BUS9	11	10.196	0.605	0.273	37.59
BUS10	11	9.898	1.639	0.74	104.9

TABLE VI. Losses Linked With And Ampere Flows In Each Segment Of Line When Panther Conductor Is Used

Line Section	Current Flow (amperes)	Power Losses (kW)	Line Section	Current Flow (amperes)	Power Losses (kW)
Line1	119.3	7.555	Line18	18.31	0.179
Line2	109.9	6.427	Line19	18.31	0.179
Line3	228.6	29.437	Line20	17.56	0.172
Line5	210.1	25.015	Line21	17.56	0.172
Line6	91.37	4.455	Line22	17.56	0.172
Line7	174.1	17.334	Line23	18.22	0.178
Line8	121.4	8.521	Line24	18.22	0.178
Line9	36.43	0.711	Line25	4.322	0.011
Line10	97.7	5.538	Line26	2.162	0.003
Line11	9.578	0.046	Line27	17.25	0.17
Line12	9.424	0.046	Line28	17	0.168
Line13	9.283	0.045	Line29	17	0.168
Line14	9.283	0.045	Line30	21.24	0.262
Line15	18.01	0.176	Line31	21.24	0.262
Line16	18.31	0.179	Line33	21.24	0.262
Line17	18.01	0.176	Line35	18.55	0.18

Analysis of Distribution Feeder Using ACSR (OSPREY) Conductor in Each Section of Feeder

The analysis of the feeder, when designed with an ACSR (OSPREY) conductor, gives the voltage level at each bus as well as the losses associated with each branch. There are a total of 78.359kw losses related to this feeder. Approximately 686,424.84 kilowatt-hours of energy, which costs up to 8,902,930.1748 Pakistani Rupees, are wasted due to annual losses. This represents a tremendous amount of energy that is wasted due to losses. The investment of 10,675,200 Pakistani Rupees should be made for the first time to purchase only the conductors. Table VII displays the voltage at each bus of the distribution feeder, as well as the MW, MVAR, and ampere loading of each bus in the feeder. Table VIII describes the losses that are linked with each section of the line and the current that flows in each section.

TABLE VII. Voltage Level At Each Bus And Loading Of Each Bus When Osprey Conductor Is Used

Bus ID	Nominal kV	Voltage (kV)	MW Loading	MVAR Loading	Amp Loading
BUS0	11	10.485	6.023	3.063	372.1
BUS1	11	10.301	5.972	2.9	372.1
BUS2	11	10.243	1.96	0.905	121.7
BUS3	11	10.184	3.832	1.84	241
BUS4	11	10.19	1.802	0.822	112.2
BUS5	11	10.076	3.512	1.646	222.2
BUS6	11	10.145	1.497	0.676	93.46
BUS7	11	9.987	2.908	1.339	185.1
BUS8	11	9.925	2.031	0.927	129.8
BUS9	11	10.127	0.597	0.269	37.35
BUS10	11	9.876	1.632	0.737	104.7

TABLE VIII. Losses Linked With And Ampere Flows In Each Segment Of Line When Osprey Conductor Is Used

Line Section	Current Flow (amperes)	Power Losses (kW)	Line Section	Current Flow (amperes)	Power Losses (kW)
Line1	119.3	5.425	Line18	18.31	0.128
Line2	109.9	4.617	Line19	18.31	0.128
Line3	228.6	21.284	Line20	17.56	0.124
Line5	210.1	18.099	Line21	17.56	0.124
Line6	91.37	3.201	Line22	17.56	0.124
Line7	174.1	12.554	Line23	18.22	0.128
Line8	121.4	6.179	Line24	18.22	0.128
Line9	36.43	0.511	Line25	4.322	0.008
Line10	97.7	4.017	Line26	2.162	0.002
Line11	9.578	0.033	Line27	17.25	0.123
Line12	9.424	0.033	Line28	17	0.122
Line13	9.283	0.032	Line29	17	0.122
Line14	9.283	0.032	Line30	21.24	0.19
Line15	18.01	0.127	Line31	21.24	0.19
Line16	18.31	0.128	Line33	21.24	0.19
Line17	18.01	0.127	Line35	18.55	0.129

Comparison and Selection of Optimal Conductor

The main objective of this paper is the selection of the optimal conductor from the conductors in each branch of the distribution system so that the distribution feeder is practically implemented with minimum capital investment, has negligible cost of energy losses to improve the annual revenue, power is delivered with maximum reliability and maintain the voltages at each bus within the limits. For this purpose, an analysis of the feeder is conducted using different types of conductors in ETAP, and the results obtained are compared, taking into account reliability, capital investment, energy cost, and voltage profile. Fig. 2 compares the voltage levels at different buses for the RABBIT, DOG, OSPREY, and PANTHER conductors. Fig. 3 and Fig. 4 combined compare the active power losses that occur in each section of the feeder for all types of conductors. Fig. 3 compares the losses in those sections that have very high losses, while Fig. 4 compares the losses in those sections that have low losses. The comparison in Fig. 2 shows that the PANTHER conductor is the best, providing an improved voltage level. Additionally, Figs. 3 and 4 show that for each section of the conductor, the minimum losses are associated with the PANTHER conductor. Fig. 5 illustrates the current in amperes that flows in each section of the distribution feeder. Fig. 7 shows the reduction in the active power losses in kilowatts in those sections of the feeder where a considerable amount of losses are associated when another conductor replaces one conductor.

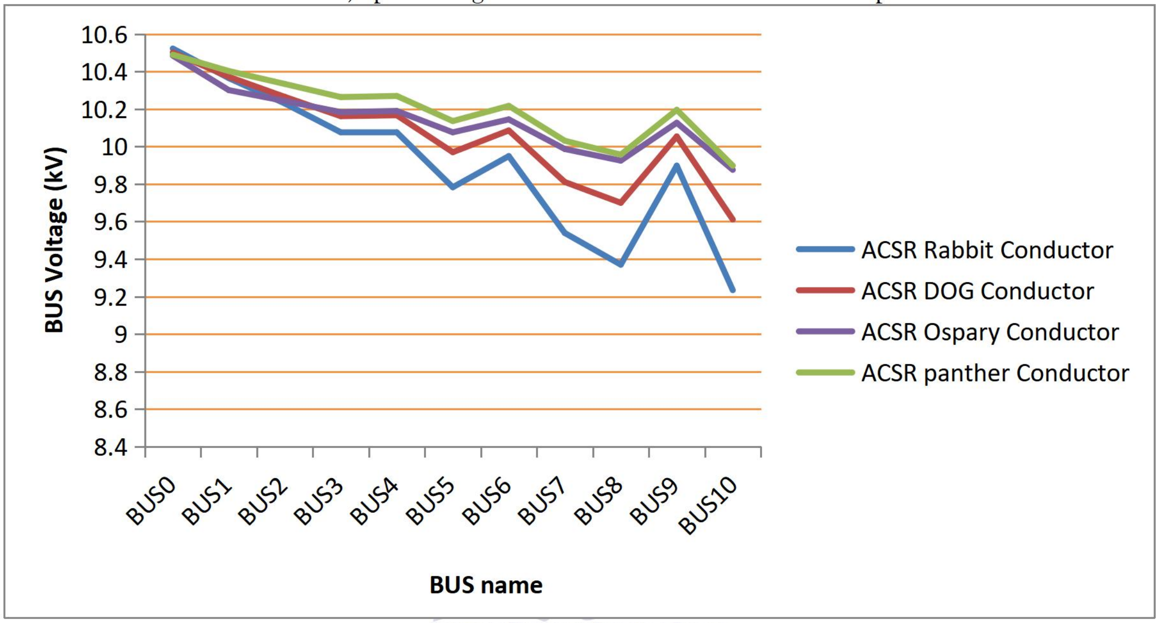

Fig. 2. Comparison of voltage level at each bus

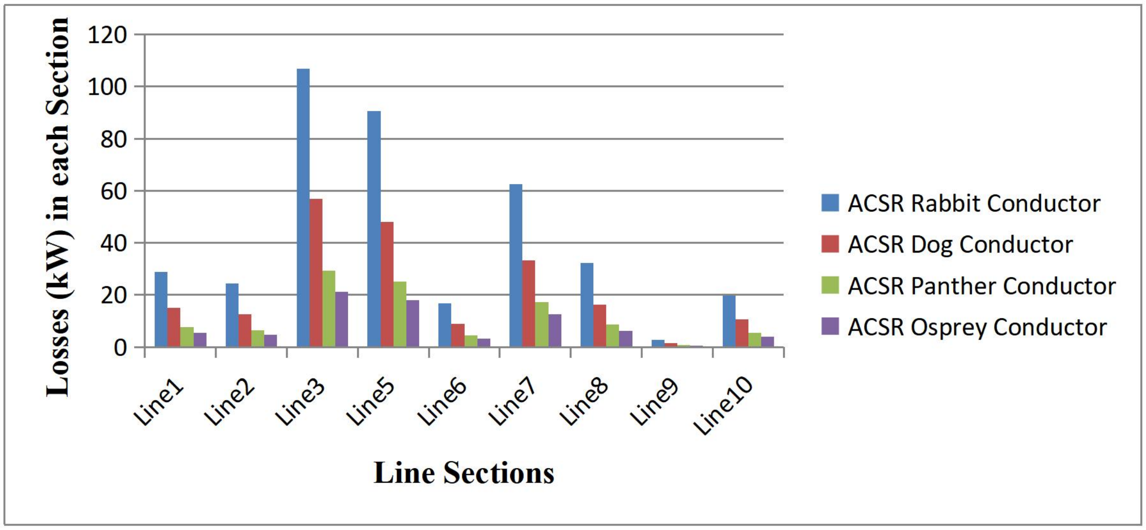

Fig. 3. Comparison of active power losses from Line1 to Line10

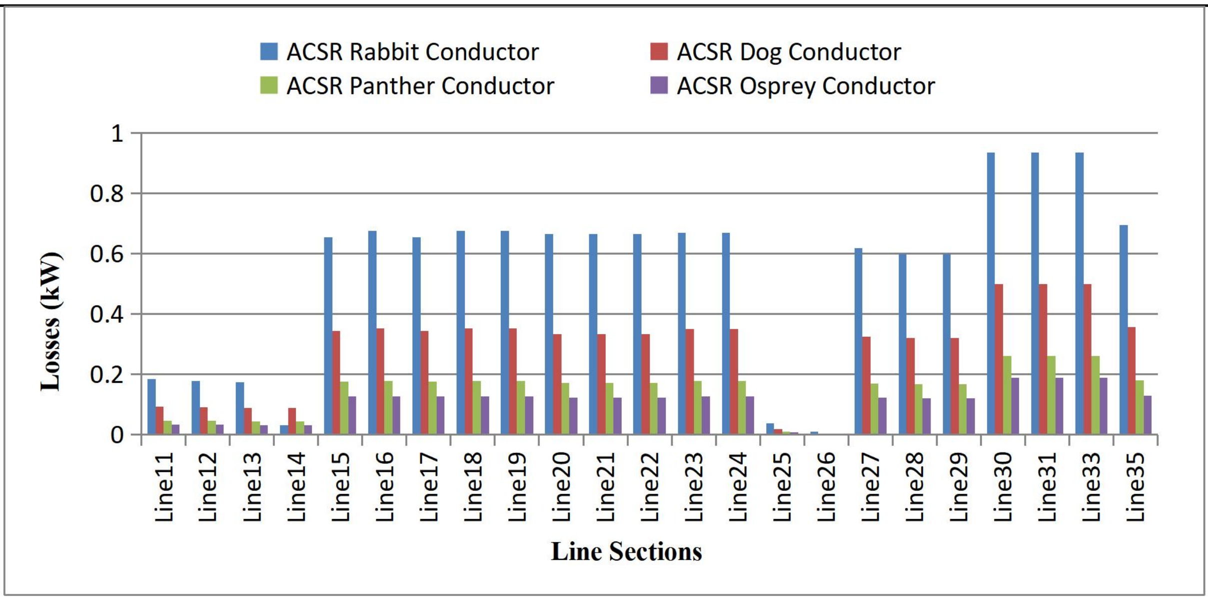

Fig. 4. Comparison of active power losses line11 to line35

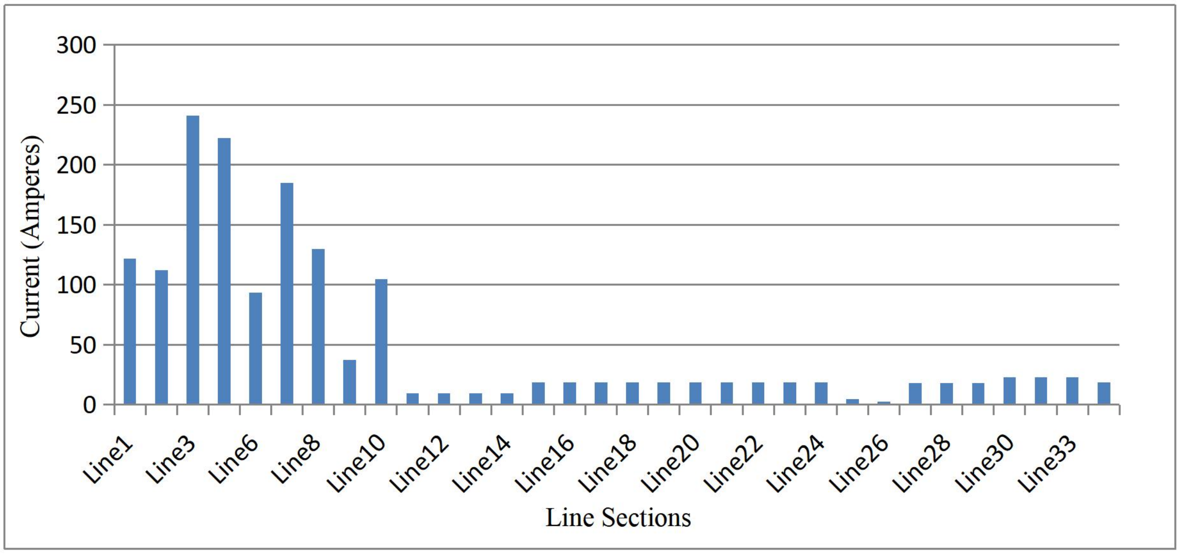

Fig. 5. Current flow in each section of the line.

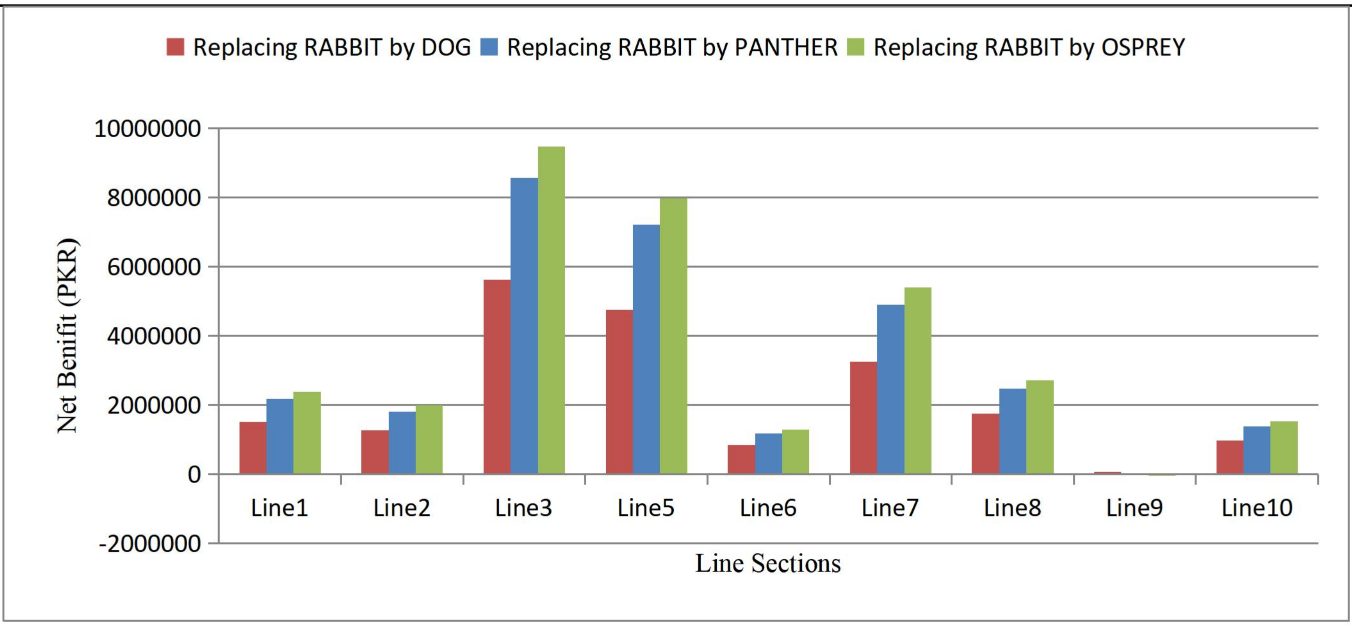

Fig. 6. Net Benefit when another replaces one conductor

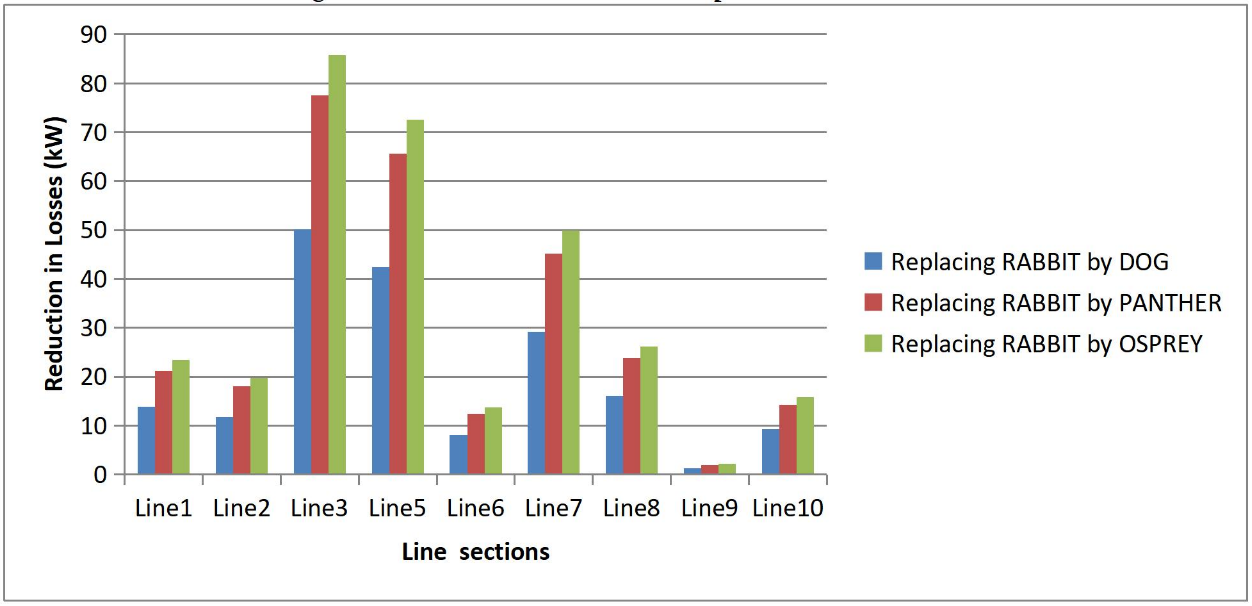

Fig. 7. Reduction in losses when another replaces one conductor

Fig. 6 shows the net benefit and net loss in PKRs in those sections of the feeder where a considerable amount of losses are associated when another conductor replaces one conductor. The net benefit is obtained as follows

Net Benefit = Increase in Revenue due to losses reduction – Increase in buying charges

From all of the comparisons done above, we obtain the result that

For reliability and an improved voltage profile, while the initial investment is not taken into account, the ACSR OSPREY conductor should be used in all sections of the feeder.

An optimum conductor for each section of the feeder while taking into account all the factors like annual revenue, reliability, improved voltage level at each bus, and cost annual energy losses should be used for each section as shown in

TABLE IX. OPTIMUM CONDUCTOR FOR EACH SECTION OF THE FEEDER

Line Section	Conductor Type	Line Section	Conductor Type
Line1	OSPREY	Line18	RABBIT
Line2	OSPREY	Line19	RABBIT
Line3	OSPREY	Line20	RABBIT
Line5	OSPREY	Line21	RABBIT
Line6	OSPREY	Line22	RABBIT
Line7	OSPREY	Line23	RABBIT
Line8	OSPREY	Line24	RABBIT
Line9	DOG	Line25	RABBIT
Line10	OSPREY	Line26	RABBIT
Line11	RABBIT	Line27	RABBIT
Line12	RABBIT	Line28	RABBIT
Line13	RABBIT	Line29	RABBIT
Line14	RABBIT	Line30	RABBIT
Line15	RABBIT	Line31	RABBIT
Line16	RABBIT	Line33	RABBIT
Line17	RABBIT	Line35	RABBIT

RESULTS

For testing purposes, the distribution feeder is designed in ETAP software, with each section of the feeder containing the optimal conductor obtained from the comparison, as shown in Table IX. After the design is completed, it is analyzed in ETAP. The analysis yields the results as shown in Tables X and XI. Table X presents the losses in kilowatts and the current in amperes in each section of the feeder when using the optimum conductors obtained in Table IX. Meanwhile, Table XI displays the voltage level, MW, MVAR, and amp loading at each bus of the feeder. These tables show that when the optimum conductor is used in the feeder, the associated power losses are at a minimum, and the voltage at each bus is at the accepted level.

TABLE X. LOSSES LINKED WITH AND AMPERE FLOWS IN EACH SEGMENT OF LINE WHEN OPTIMUM CONDUCTOR IS USED

Line Section	Current Flow (amperes)	Power Losses (kW)	Line Section	Current Flow (amperes)	Power Losses (kW)
Line1	122.3	7.532	Line18	18.81	0.7
Line2	112.8	6.407	Line19	18.81	0.7
Line3	241.5	29.357	Line20	18.47	0.674
Line5	222.6	24.946	Line21	18.47	0.674
Line6	93.92	4.439	Line22	18.47	0.674
Line7	185.3	17.286	Line23	18.75	0.695
Line8	129.9	8.498	Line24	18.75	0.695
Line9	37.49	1.434	Line25	4.594	0.042
Line10	104.7	5.521	Line26	2.298	0.01
Line11	9.585	0.182	Line27	18.33	0.665
Line12	9.521	0.179	Line28	18.22	0.657
Line13	9.462	0.177	Line29	18.22	0.657
Line14	9.462	0.177	Line30	22.77	1.025
Line15	18.66	0.689	Line31	22.77	1.025
Line16	18.81	0.7	Line33	22.77	1.025
Line17	18.66	0.689	Line35	18.9	0.706

TABLE XI. VOLTAGE LEVEL AT EACH BUS AND LOADING OF EACH BUS WHEN OSPREY CONDUCTOR IS USED

Bus ID	Nominal kV	Voltage (kV)	MW Loading	MVAR Loading	Amp Loading
BUS0	11	10.491	6.082	3.008	373.4
BUS1	11	10.404	6.054	2.938	373.4
BUS2	11	10.335	1.988	0.918	122.4
BUS3	11	10.265	3.872	1.858	241.5
BUS4	11	10.271	1.827	0.833	112.8
BUS5	11	10.138	3.54	1.659	222.7
BUS6	11	10.218	1.515	0.684	93.93
BUS7	11	10.032	2.926	1.347	185.3
BUS8	11	9.959	2.039	0.93	130
BUS9	11	10.185	0.603	0.272	37.5
BUS10	11	9.9	1.637	0.739	104.8

Table XII shows the total initial cost, total power, and energy losses associated with the feeder, and the cost of annual energy losses of the feeder when the feeder is designed with RABBIT, DOG, PANTHER, OSPREY, or with the optimum conductor. Fig. 8 compares the total initial investments and annual energy costs of the feeder.

Table XII. INITIAL COST, TOTAL POWER, AND ENERGY LOSSES, AND COST OF ANNUAL ENERGY LOSSES OF THE FEEDER FOR DIFFERENT CONDUCTORS USED

Type of conductor used in feeder	Initial cost	kW losses	Annual energy losses	Cost of yearly energy losses
RABBIT Conductor	2227200	395.41	3463791.6	44925377.05
DOG Conductor	4454400	209.523	1835421.48	23805416.6
PANTHER Conductor	9600000	108.422	949776.72	12318604.06
OSPREY Conductor	10675200	78.359	686424.84	8902930.175
Optimum conductor	4408800	118.837	1041012.12	13501927.2

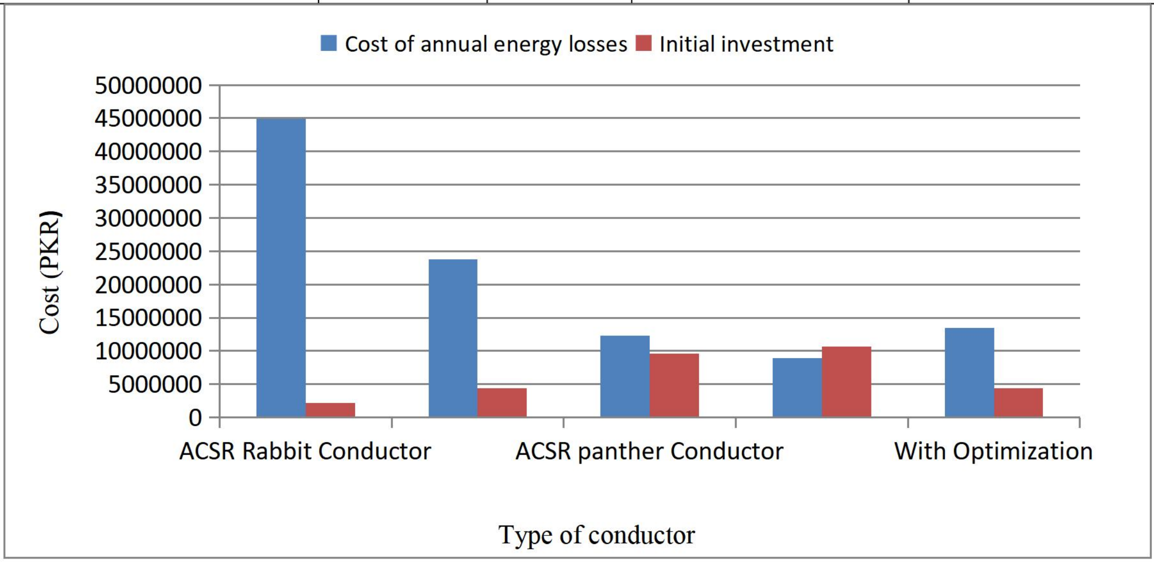

Fig. 8. Comparison of initial investments and costs of annual energy losses

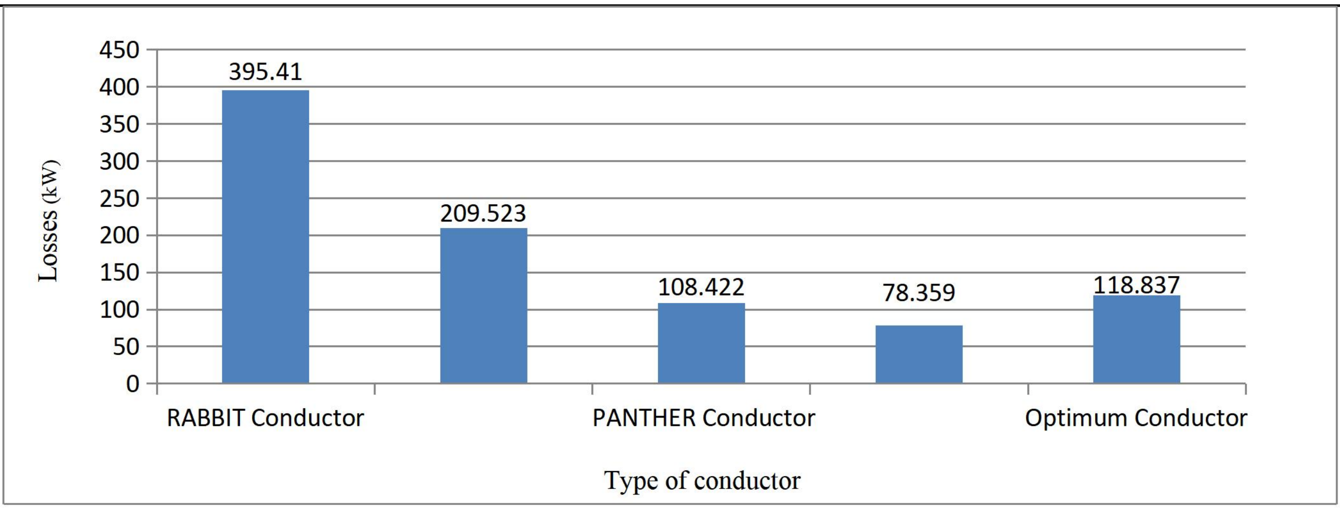

Fig. 9. Total power loss associated with the distribution feeder

Fig. 9 compares the total power loss associated with the distribution feeder. From the comparison, it is clear that there is about a 69.95% decrease in the amount of losses and also about a 69.95% increase in annual revenue if we use the optimal conductor instead of the RABBIT conductor that is usually used. Using optimal conductors in each section of the feeder results in improved system stability, a better voltage profile, reduced active and reactive power losses, and enhanced energy handling ability, all while minimizing costs.

V. CONCLUSION

The optimal conductor selection for a distribution feeder, as determined using ETAP software, is presented. A load flow study of the distribution feeder using different types of conductors is conducted using ETAP software. The comparison of the results obtained from the load flow study and the total initial costs is done. From the comparison the optimal conductor for each section of the feeder is selected. The distribution feeder designed with the selected optimum conductor is then analyzed in ETAP software. The power loss reduction, voltage profile improvement and the stability of the system is obtained with the minimum initial cost which shows the effectiveness of the proposed method.

REFERENCES

[1] D. P. Bernardon, V. J. Garcia, A. S. Q. Ferreira, and L. N. Canha, "Multicriteria distribution network reconfiguration considering subtransmission analysis," IEEE Transactions on Power Delivery, vol. 25, pp. 2684-2691, 2010.

[2] M. Dalila, M. Khalid, and M. M. Shah, "Distribution transformer losses evaluation under non-linear load," in Power Engineering Conference, 2009. AUPEC 2009. Australasian Universities, 2009, pp. 1-6.

[3] NTDC (National Transmission and Dispatch Company). (25/04/2017). Power System Statistics 2015-16. Available: www.ntdc.com.pk/Files/Power%20System%20Statistics%2041st%20Edition.pdf

[4] H. Tram and D. Wall, "Optimal conductor selection in planning radial distribution systems," IEEE Transactions on Power Systems, vol. 3, pp. 200-206, 1988.

[5] G. Salis and A. Safigianni, "Long-term optimization of radial primary distribution networks by conductor replacements," International Journal of Electrical Power & Energy Systems, vol. 21, pp. 349-355, 1999.

[6] S. Mandal and A. Pahwa, "Optimal selection of conductors for distribution feeders," IEEE Transactions on Power Systems, vol. 17, pp. 192-197, 2002.

[7] S. Sivanagaraju, N. Sreenivasulu, M. Vijayakumar, and T. Ramana, "Optimal conductor selection for radial distribution systems," Electric power systems research, vol. 63, pp. 95-103, 2002.
[8] Z. Wang, H. Liu, D. C. Yu, X. Wang, and H. Song, "A practical approach to the conductor size selection in planning radial distribution systems," IEEE Transactions on Power Delivery, vol. 15, pp. 350-354, 2000.
[9] M. M. Legha, "Determination of exhaustion and junction of in distribution network and its loss maximum, due to geographical condition, MS. c Thesis," Islamic Azad University, Saveh Branch, Markazi Province, Iran, 2011.
[10] M. M. Legha and H. Gadari, "Technical and Economical Evaluation of Solar Plant for Electricity Supply Anar City Residential Customers," Middle-East Journal of Scientific Research, pp. 455-460, 2013.
[11] J. F. Franco, M. J. Rider, M. Lavorato, and R. Romero, "Optimal conductor size selection and reconductoring in radial distribution systems using a mixed-integer LP approach," IEEE Transactions on Power Systems, vol. 28, pp. 10-20, 2013.
[12] M. M. Legha and M. Mohammadi, "Aging Analysis and Reconductoring of Overhead Conductors for Radial Distribution Systems Using Genetic Algorithm," Journal of Electrical Engineering & Technology (JEET), pp. 1-8, 2014.
[13] M. M. Legha, H. Noormohamadi, and A. Barkhori, "Optimal conductor selection in radial distribution using bacterial foraging algorithm and comparison with ICA method," WALIA Journal, pp. 1-8, 2015.
[14] C. Soni, P. Gandhi, and S. Takalkar, "Design and analysis of 11 KV distribution system using ETAP software," in Computation of Power, Energy Information and Communication (ICCPEIC), 2015 International Conference on, 2015, pp. 0451-0456.
[15] D. Das, D. Kothari, and A. Kalam, "Simple and efficient method for load flow solution of radial distribution networks," International Journal of Electrical Power & Energy Systems, vol. 17, pp. 335-346, 1995.
[16] A. Abdulkareem, C. Awosope, H. Orovwode, and A. Adelakun, "Power Flow Analysis of Abule-Egba 33-kV Distribution Grid System with real network Simulations," IOSR Journal of Electrical and Electronics Engineering, vol. 9, pp. 67-80, 2014.