Load Flow Analysis and Loss Reduction Activities: A Case Study on Kawasoti 132/33/11 kv Substation

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Abstract

This paper deals with the study of energy flow patterns in INPS connected 132KV/ 33KV/11KV Kawasoti Sub-Station. From the monthly data as of April and May 2020, the base load for 30 MVA 132/33 KV transformer is about 12 MW and peak load is around 15 MW. Load forecast of 132/33/11 KV Kawasoti Sub-Station shows that the cumulative load growth percentage is around 70 % and around 8.75% per year. The peak load in 2020 was around 23.53 MW and it would approximately reach 40 MW at the end of fiscal year 2028. Load flow analysis as of 2020 shows total distribution loss was found to be 1.7833 MW when the demand is 23.658 MW at 0.7141 lagging and reactive power loss of 8.907 MVAR is found. Estimated total distribution loss for the year 2028 would be 3.851 MW when the demand is 40.238 MW at 0.76 lagging and reactive power loss of 20.572 MVAR. After the placement of a capacitor bank of 7000 KVar and 5000 Kvar on MV and LV Bus-Bar respectively, the total distribution loss was found to be 0.8695 MW with pay-back period of 1.427 Years for year 2020. After the placement of a capacitor bank of 10000 KVar and 7000 Kvar on MV and LV Bus-Bar respectively, the total distribution loss would be 2.2563 MW with pay-back period of 1.158 Years for forecasted condition. The simulated model, result and analysis are presented in this paper.

Keywords: Load Factor, Load Flow, Load Forecast, OCP, System Loss

Introduction

Electrical power is a critically important component affecting productivity, standard of living, prosperity and strength of any nation. The district of Nawalparasi (East), which contains the targeted area of the research area, Kawasoti is a newly industrialized area where new factories are being constructed, infrastructure being developed, and the inhabitants are working to eliminate economic disparity. The commerce and industries in the area show steady growth, which is attracting people to the area and increasing the population. The new arrivals, with expectations of economic growth, then demand a reliable electricity supply. The Bharatpur-Bardaghat 132 KV transmission line is tapped off on Kawasoti sub-station with the transformer of rating 30MVA, 132/33 KV (Agency, May 2006). 33 KV line is distributed to two feeders namely Kawasoti and Mukundapur. 16 MVA, 33/11 KV transformer output is distributed to Industrial, Pragatinagar and Rajahar feeder respectively. In order to use the energy efficiently, different losses within the system must be minimized. The major losses within the INPS are among the distribution side (Authority, August 2020). These research activities were performed to identify the energy consumption pattern and recommended the technical loss reduction activities on Kawasoti 132/33/11 kV sub-station in order to improve voltage regulation, power outages, and distribution loss reduction.

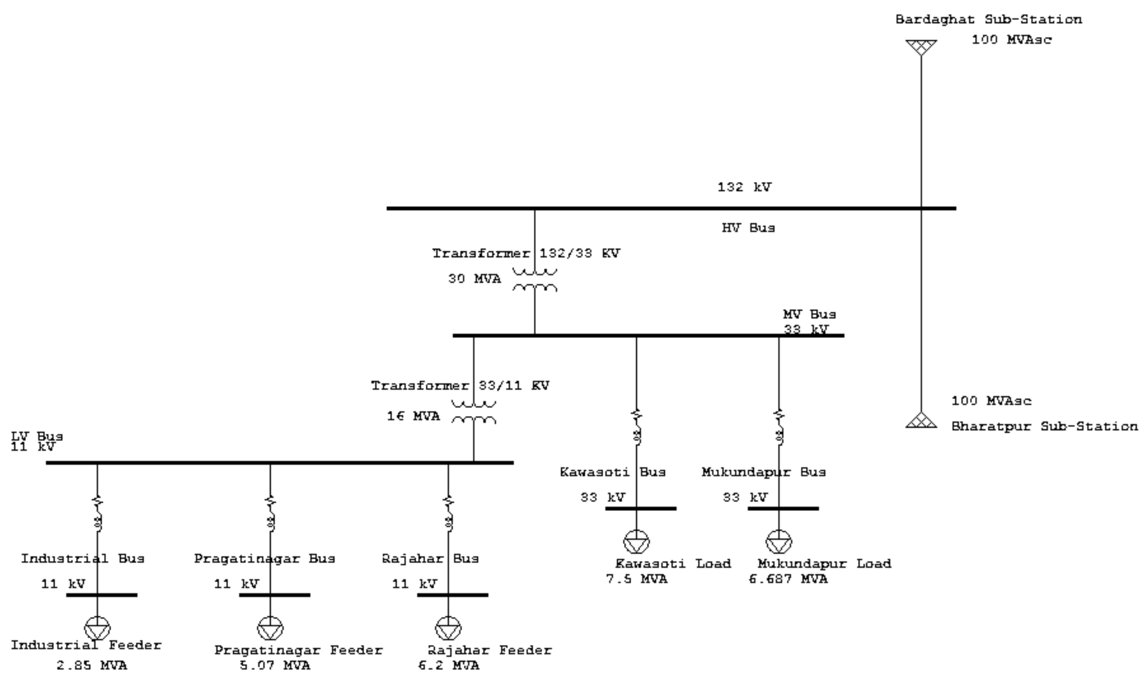

Figure 1: Single line diagram of Kawasoti Sub-station

Methodology

To analyze the load consumption pattern and recommended the technical loss reduction activities on Kawasoti 132/33/11 kV sub-station on the Integrated Nepal Power System, following procedures were follows (Gupta, Gurung, K.C, & Timalsina, 2008) (L.V, 2017).

Data Collection

The necessary data were collected from Kawasoti 132/33/11 kV sub-station log books, NEA annual reports, and papers related to load flow analysis of INPS (Authority, August 2020). Most of the data are collected from reports and records of the Kawasoti 132/33/11 kV sub-station itself through direct personal investigation. So, it undertakes more reliable and accurate.Modelling

An appropriate model of the system was built in the Electrical Transient Analyzer Program (ETAP). The first model developed in this research was an existing system with load demand. After that, using the ETAP tools OCP, the rating of the capacitor had been determined and placed in the respective busbar (Mishra, Karki, & Gyawali, 2014). Next model was developed by estimating the future demand based on previous load growth patterns and developed a model to minimize the losses for future scenarios using OCP tools in ETAP (Program, March 2014).

Load Flow

After the development of two different models, they were simulated on ETAP. Load flow analysis was conducted to determine the power flow through different lines, line losses and voltage at different buses (Krishnamurthy, Aug 2013) (Kumar, Aug 2013).

ETAP

ETAP stands for Electrical Transient Analyzer Program. ETAP is the most comprehensive analysis tool for the design and testing of power systems available. Using its standard offline simulation modules, ETAP can utilize real-time operating data for advanced monitoring, real-time simulation, optimization, energy management systems, and high-speed intelligent load shedding (Program, March 2014). The model was built in ETAP and load flow and Optimal Capacitor Placement (OCP) was performed. The result so obtained is used in the analysis of the system.

Load forecasting

Parametric methods have been adopted which is based on relating load demand to its affecting factors by a mathematical model. The model parameters are estimated using statistical techniques on historical data of load and its affecting factors like industrialization, urbanization, population growth rate, electrification expansion (Kothari, 1994). So, in order to meet the future demand, planning must be carried out earlier. For the area of Nawalparasi (East), Kawasoti 132/33/11 KV sub-station is supplying the energy demand. Load forecast of Kawasoti 132/33/11 KV sub-station based on previous load growth pattern shows that the load growth rate is increasing in nature each year. The peak load on 2020 was around 23.53 MW and it would approximately reach 40 MW at the end of fiscal year 2028 i.e would increase by around 16.5 MW. The cumulative percentage growth rate is around 70 % and around 8.75% per year.

Table 1: Yearly Load data of Kawasoti 132/33/11 kV sub-station

Year	Pragatinagar Feeder (MW)	Rajahar Feeder (MW)	Industrial Feeder (MW)	Kawasoti Feeder (MW)	Mukundapur Feeder (MW)	Total Load (MW)
2017	2.75	3.68	1.7	4.38	4.52	17.03
2018	3.85	3.82	1.99	5.07	5.03	19.76
2019	4.05	4.07	2	5.9	5.34	21.36
2020	4.25	4.96	2.15	6	6.17	23.53
2021	4.9	5.155	2.3	6.76	6.58	25.695
2022	5.1	5.725	2.38	7.225	7.15	27.58
2023	5.525	6.267	2.53	7.655	7.77	29.747
2024	5.95	6.65	2.645	8.267	8.26	31.772
2025	6.262	7.206	2.76	8.715	8.855	33.798
2026	6.687	7.668	2.892	9.236	9.41	35.895
2027	7.056	8.138	3.007	9.766	9.952	37.920
2028	7.425	8.647	3.131	10.250	10.527	39.981

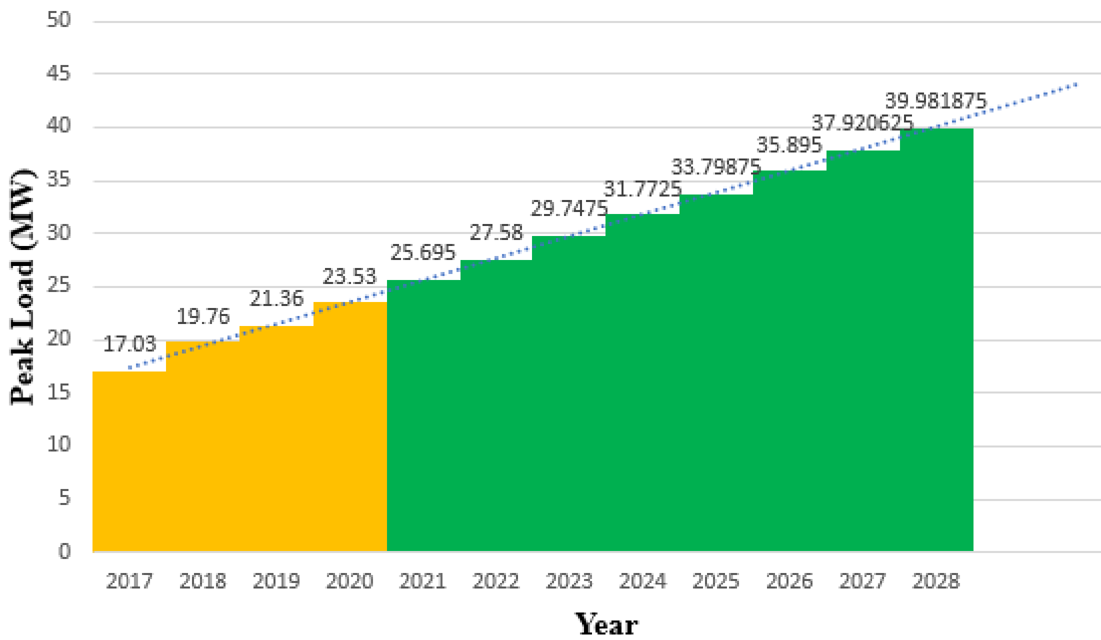

Figure 2: Load Forecast of Kawasoti 132/33/11 kV sub-station

Load flow result and analysis

Load flow was simulated for two different conditions i.e without OCP and with OCP for load of year 2020 and 2028 on ETAP. OCP is a mathematical tool that consideration of Per Kvar cost of capacitor bank, Operating cost of per bank per year, Cost of each KWh loss in $/KWh, load levels, maximum, average and minimum, Planning period (years), Total system loss at load level and so on.

Load Flow Analysis of 2020 load without OCP

Peak load of 2020 was simulated in ETAP with making necessary assumptions and the result shows that 30 MVA 132/33 KV transformer was operating at load exceeding the branch capability. 30 MVA transformer total loss was 138.8 KW with total distribution loss of 1.7833 MW when the demand was 23.658 MW at 0.7141 lagging and reactive power loss of 8.907 MVAR.

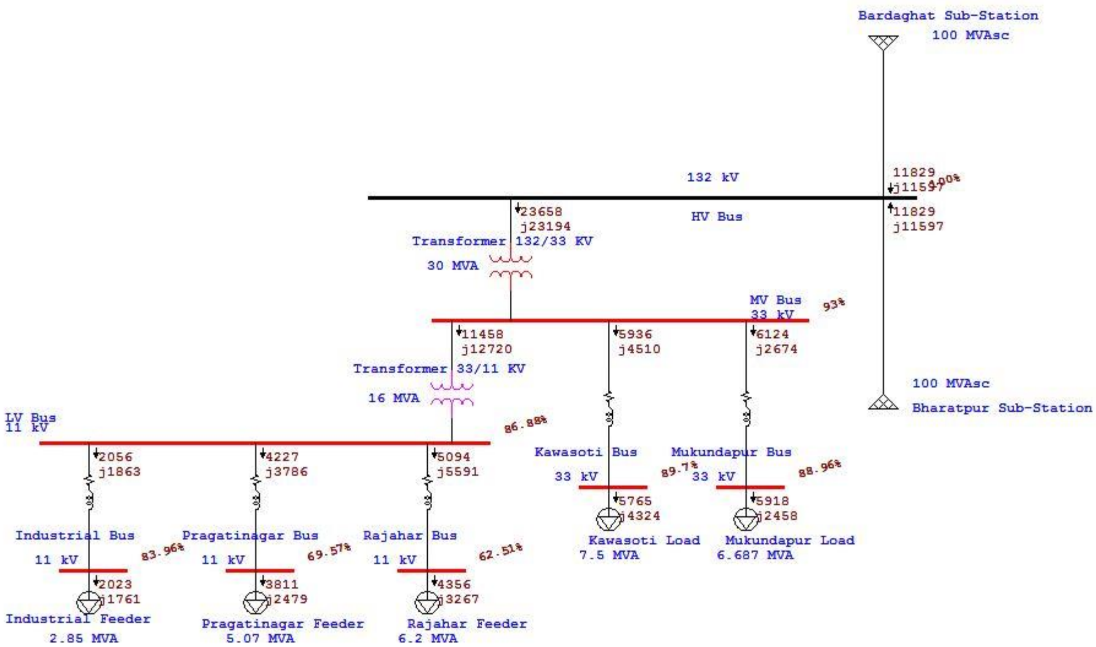

Figure 3: Load flow of 2020 without OCP

Load Flow Analysis of 2020 load OCP

Peak load of 2020 after OCP was simulated in ETAP with making necessary assumption and result shows that capacitor bank of rating 7000 kVAR and 5000 kVAR need to be placed on MV Bus-Bar and LV Bus-Bar respectively. After the placement of capacitor bank the total distribution loss was found to be 0.8695 MW when the demand is 26.524 MW at 0.99 lagging and reactive power loss of 2.849 MVAR is found.

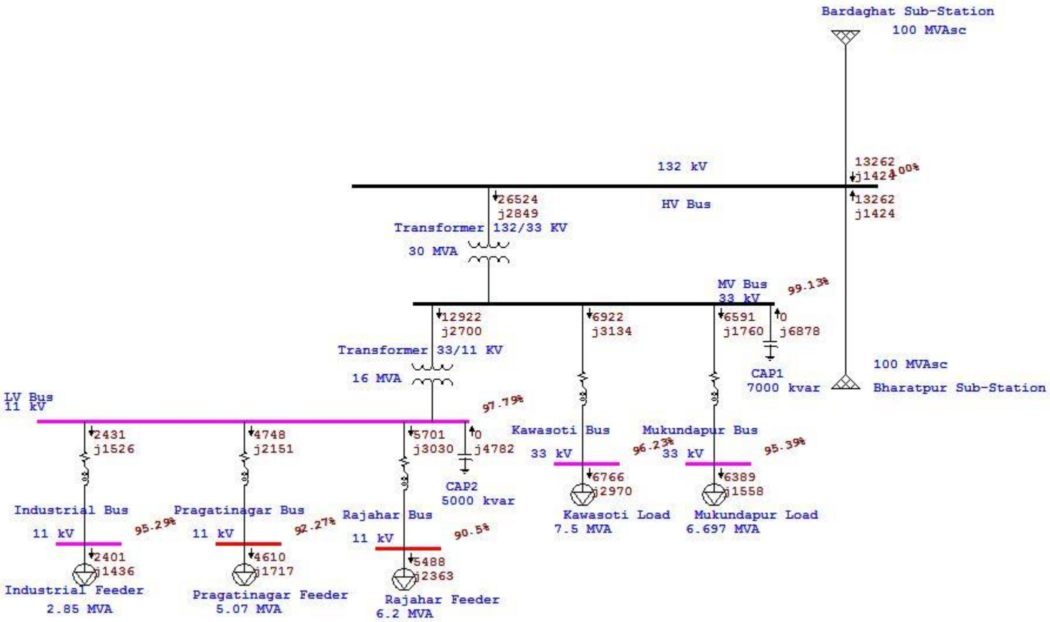

Figure 4: Load flow of 2020 with OCP

Load Flow Analysis of estimated load without OCP

Peak predicted load of 2028 was simulated in ETAP software with making necessary assumption and result shows that 30 MVA 132/33 KV transformer and 16 MVA 33/11 KV transformer would be operating at load exceeding the branch capability.30 MVA transformer total loss would be 353.7 KW and the total distribution loss would be 3.851 MW when the demand is 40.238 MW at 0.76 lagging and reactive power loss of 20.572 MVAR.

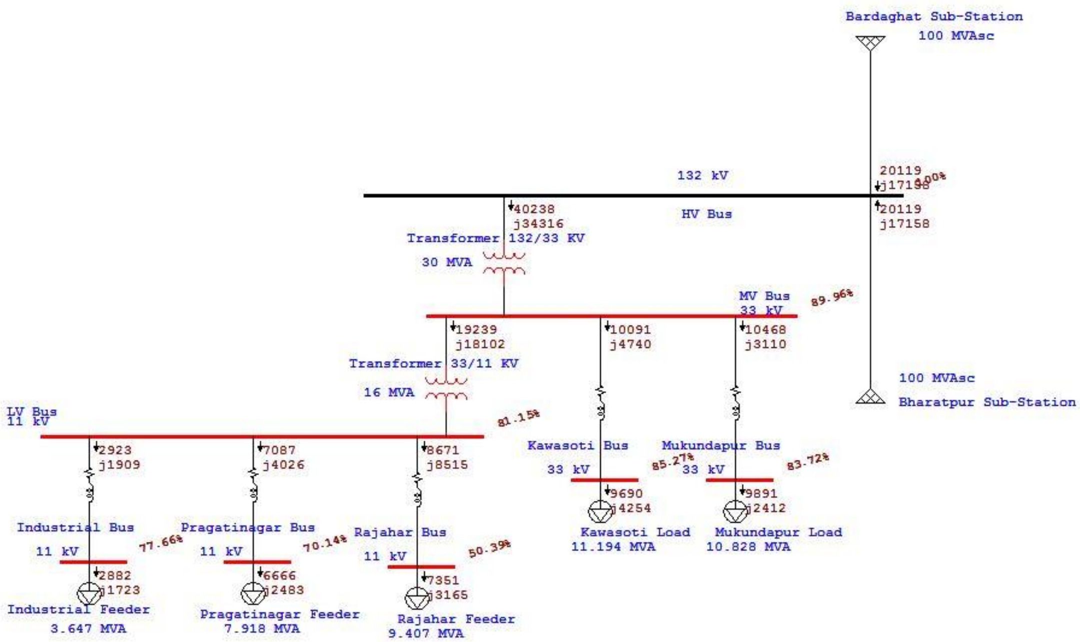

Figure 5: Load Flow of estimated load without OCP

Load Flow Analysis of estimated load with OCP

Peak predicted load of 2028 after OCP was simulated in ETAP and result shows that capacitor bank of rating 10000 kVAR and 7000 kVAR need to be placed on MV Bus-Bar and LV Bus-Bar respectively. After the placement of capacitor bank the total distribution loss would be 2.2563 MW when the demand is 40.53 MW at 0.9678 lagging and reactive power loss of 10.544 MVAR.

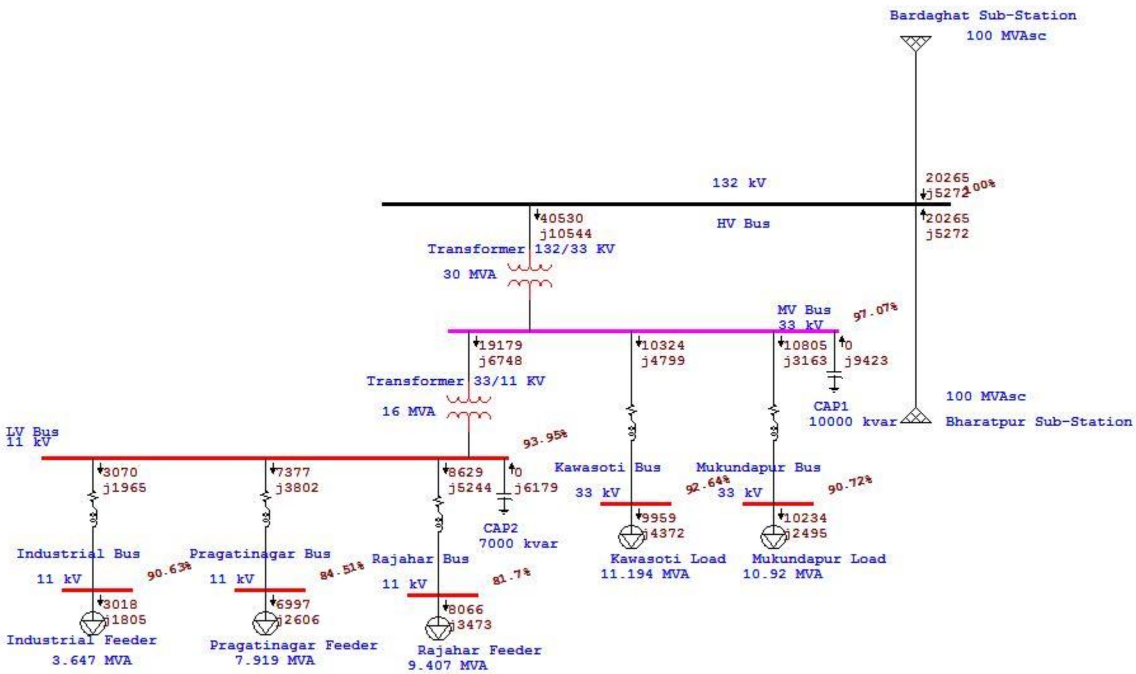

Figure 6: Load Flow of estimated load with OCP

Comparison of active power loss

The total distribution loss was found to be 1.7833 MW when the demand was 23.658 MW at 0.7141 lagging and reactive power loss of 8.907 MVAR on 2020 and would be 3.851 MW on forecasted load when the demand is 40.238 MW at 0.76 lagging and reactive power loss of 20.572 MVAR without OCP. After OCP the total distribution loss was found to be 0.8695 MW on 2020 and 2.2563 MW on estimated load.

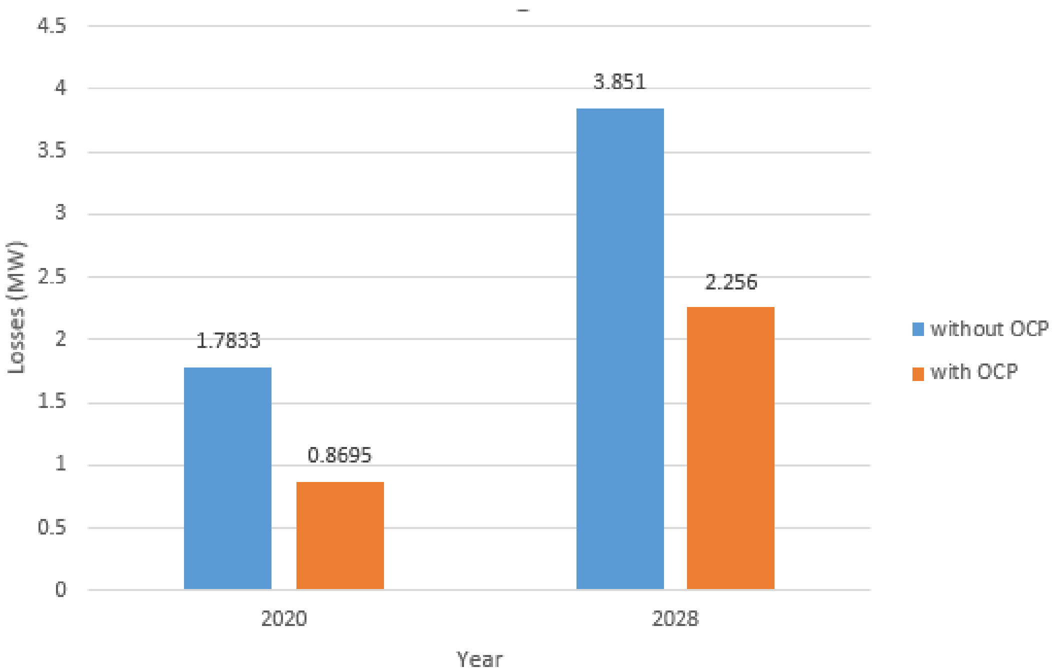

Figure 7: Comparison of active power loss

Comparison of payback Period

After the placement of capacitor bank of 7000 KVar and 5000 Kvar on MV and LV Bus-Bar respectively, the energy saving was found to be 5603421.6 kWh with annual load factor of 0.7. The pay-back period is found to be 1.427 Years for year 2020. After the placement of capacitor bank of 10000 KVar and 7000 Kvar on MV and LV Bus-Bar respectively, the total energy saving would be 9781153.2 kWh with pay-back period of 1.158 Years for future condition.

Table 2: Comparison of Payback period

Year	KVAR	Cost/KVAR ($)	Total Cost of OCP ($)	Energy saving/year (kWh)	Cost/kWh ($)	Total cost of energy saved ($)	Pay-back period (Year)
2020	12000	40	480,000	5,603,421.6	0.06	336,205.3	1.427
2028	17,000		680,000	9,781,153.2		586,869.2	1.158

Conclusion

The load flow analysis and comparison carried out in this research has led to the conclusion that, the load growth rate is increasing in nature each year and would increase by 16.5 MW in next eight years. Total distribution loss was found to be 1.7833 MW and would be 3.851 MW by the end of 2028. After the placement of a capacitor bank of suitable rating on MV and LV bus-bar, the total distribution could be minimized with a feasible payback period. Hence, for the present condition the operating indices of Kawasoti Sub-Station is satisfactory for meeting the load demand and needs to be upgraded soon for fulfilling the energy demand of Nawalparasi (East) area and appropriate measures should be undertaken to increase the system performance.

To prevent hooking, a thorough loss reduction program will be put in place. This program will involve using Time-of-Day (TOD) meters to regularly monitor and analyze major industrial and commercial consumers. To prevent mistakes, this entails swapping out electromechanical meters for digital ones and repairing mismatched current transformers. Employees must actively look into meter manipulation and theft with the assistance of the local government. To further minimize technical losses, actions like updating overloaded conductors and transformers, installing new feeders and transformers in high-loss locations, and swapping out bare conductors for Ariel Bundled Conductors (ABC) cables should be implemented. Additionally, the use of capacitor banks for reactive power management and the switch from electromechanical to three-phase smart meters are intended to reduce distribution losses and improve voltage regulation.

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