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Voltage Profile Improvement and Power Loss Reduction of Bairiya and Bankul Feeder of 33/11 kV Gaur Substation

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Abstract

One of the most critical areas of power loss and low voltage profile occurs in Radial Distribution System (RDS) due to undersized conductors, overloading of bus bar, longer feeder length etc. The research focuses in voltage profile improvement and power losses reduction for performance improvement of distribution system. For this purpose, two feeders of Gaur substation of 33/11 kV are selected. Newton Raphson method is employed for carrying out the load flow analysis. The analysis is done for both the cases, i.e. base case loading and peak case loading. The charging substation of 8 MVA rating is injected at the bus with minimum voltage for Bankul feeder since it has poor voltage regulation to enhance the voltage profile and reduce the power losses. Replacement of conductors and transformer tap setting simultaneously helps in performance improvement of distribution system feeder. The active power loss of Bairiya feeder is 129 kW and 391 kW for base case and peak load condition without reconfiguration respectively. Replacement of the weasel and rabbit conductors with dog conductor and adjustment of transformer tap settings in Bairiya feeder reduces the power losses to 88 kW and 329 kW for base load and peak load respectively. This elucidates saving of 63 kW and 41 kW for Bairiya feeder in peak case and base case respectively. The minimum bus voltage for Bankul feeder during peak case loading is 5.25 kV, i.e. 47% of the grid voltage. This violates the NEA Grid Code Standard, 2011. Hence, after injection of 8 MVA substation in Bankul feeder, the bus voltage is improved to 10 kV, i.e. about 91% of the grid voltage. Hence, the feeder now meets the NEA Grid Code Standard. Total power loss for peak loading of Bankul feeder is found to be 152.16 kW, which results in saving of 1275.8 kW for peak case condition. On the other hand, 284 kW power is saved from base case condition after injecting Maulapur substation at Bankul feeder.

Keywords

Radial Distribution System (RDS),Electrical Transient Analyzer Program (ETAP),Nepal Electricity Authroity (NEA), Voltage Profile, Power loss

1. Introduction

Distribution network plays a critical role in the power system since is the primary link to the consumers and load centres[1]. Proper planning of the distribution system is one of the pre-requisites for supplying the quality of power of high reliability and efficiency to the consumers and load centres. Evaluation of the existing distribution system is considered as the initial step in understanding the primary issues and requirements of the system. The selected distribution feeders suffer from several technical problems due to longer radial length, overloaded conductors, unbalancing of load etc. There are more losses in the feeder and exceeds 30% voltage fluctuations that violates NEA Grid Code Standard 2011. Currently, the total installed capacity of power plants and projects that generate electricity is 1451.3354 MW, which is inclusive of Hydro, Solar and Thermal Power Plants [2]. Till date, the maximum voltage of 400 kV has been integrated and energized to Integrated Nepal Power System (INPS). Currently, there are forty-one existing High Voltage 132 kV Transmission Lines with circuit length of about 3129.54 km. Similarly, there are five existing High Voltage 400/220 kV Transmission Lines with circuit length of about 332.60 km and there are sixteen High Voltage 66 kV Transmission Lines with circuit length of about

514.46 km [3]. The transmitted power to the load centre needs to be distributed to the consumers through various feeders called distribution of electrical energy. In investigating the distribution system feeders of 33/11 kV Gaur substation, there are four feeders out of which Bankul feeder is the longest feeder in length having a total distance of around 89 km when compared to the other three feeders. Due to long radial length and overloaded conductors, the voltage profile and power losses are much higher when compared to the other feeders. Two feeders are selected for the analysis and performance improvement of distribution system feeders. Power flow studies is carried out for both the cases i.e. peak case loading and normal case loading. Technical losses can be minimized by feeder reconfiguration, replacement of undersized conductors, sectionalization of the feeders into two sections or injection of charging substation at the bus with minimum voltage. The main contribution of this research work is that it analyses two 11 kV distribution feeders of Gaur substation and suggests the suitable technical solutions for the performance improvement of Distribution System Feeder. Figure 1 shows the main feeders of 33/11 kV Gaur Substation.

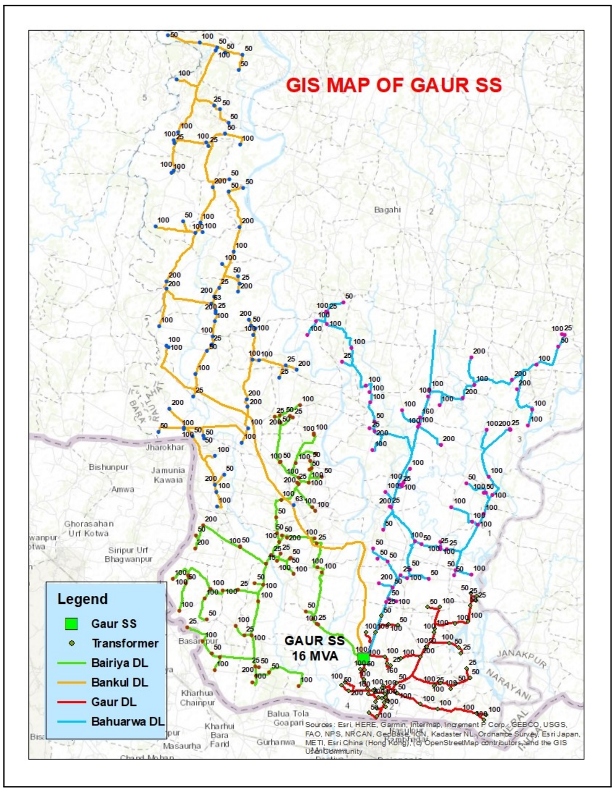

Figure 1: Main feeders of Gaur substation

2. Literature Review

The distribution system losses of Nepal Electricity Authority (NEA) is estimated to be increased to 11.64% from 10.28% as compared to the last fiscal year. [3]. Lots of research have been carried out in the field of distribution system for better planning and optimization of system network. [4] clearly showed the tentative losses of Industrial Feeder of 11 kV voltage level in Kawasoti Distribution Centre considering both the technical as well non-technical aspects, using Electrical Transient and Analysis Program (ETAP). From this study, the aggregate line and commercial loss was found to be 1.66% and the actual total loss of industrial feeder was 2.388 of the total imported energy and technical loss was only 0.385%. Similarly, [5] carried out load flow analysis of the primary distribution feeder network employing Power System Analysis Tool (PSAT). From this study, it was found that 2.60378 MW of active power and 2.30945 MVAR of reactive power was required to electrify the affected area of UKHPP. For increased performance with Distributed System Generation (DG) units or Distributed Energy Resources (DERs), load flow analysis of 33/11 kV RSU injection substation was taken into consideration for the analysis. The branch power losses were minimized, resulting in an increase in the total power near the load centres or the end of the consumers. The impact of injection of DGs or DERs into the feeder minimizes branch power losses by 93.77%. The minimum bus voltage presently sustained was 10.8 kV in the base case [6].[7] determined Loss Sensitivity Factors to determine the candidate buses for optimal sitting and sizing of capacitor banks. The load flow was carried by Backward/Forward Sweep (BFS) algorithm. The study was carried out with test bus systems as 15-bus and 34-bus Radial Distribution Systems. Ant Colony Optimization (ACO) technique was adopted for reducing the distribution system losses, power factor improvement and voltage profile improvement. Optimal capacitor placement helps in improvement of performance of distribution system feeder. Further, injection of Distribution Energy Resources (DERs) enhances the performance furthermore [8] [9]. In [10], using secondary data, it was discovered that the distribution system technical loss of the feeder was 38%, and for the existing feeder, the loss was about 22% considering the technical aspects. For the existing distribution system feeder, replacement of conductor in the feeder reduces the losses in terms of technical aspects by almost 4% and efficiency by 82.94%. Genetic Algorithm (GA) is developed for the optimization [11] . Further, it clearly presents to what extent we can improve the performance of distribution system without overhauling the entire network. The developed simulation and algorithm is firstly implemented in IEEE 33 bus system to improve its voltage profile and reduce the power system losses. The effectiveness of the developed system is validated as it reduced the voltage drop by 5.66% and the power loss by 25.96%. With the solution validated, the algorithm is further implemented in the case of Pulchowk DCS. After re-configuring the system in different individual cases, optimum network reconfiguration is selected that improved the voltage profile by 3.85%, and the active and reactive power losses by 44.29% and 45.54% respectively from the base case scenario.

3. Research methodology

The flow chart for the power flow simulation of the distribution feeder is shown in Figure 2.

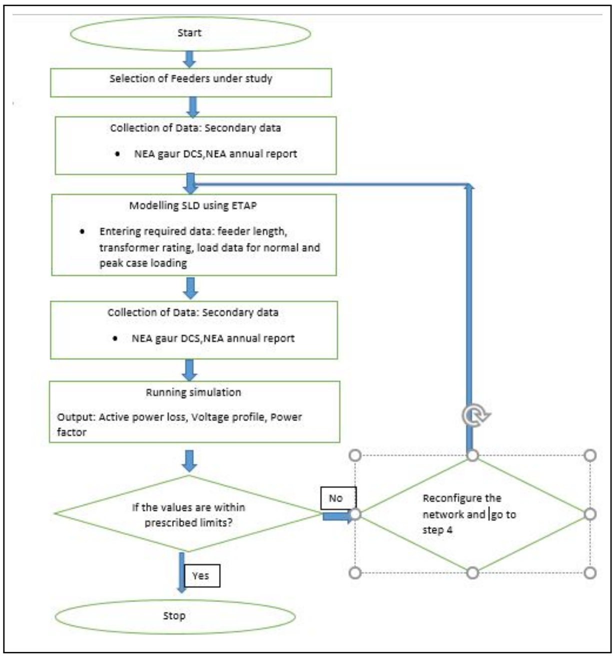

Figure 2: Flow chart for power flow analysis using ETAP

3.1 Power losses

In distribution system, power loss mainly occurs in transformer and feeder lines. In case of distribution systems, distribution system losses can be accounted in terms of technical as well as non-technical aspects. Non technical losses usually occur due to the theft of electricity and even errors in meter reading. Power losses can be calculated using the following equations

$$PeakLoad = \sqrt{3} \times SystemVoltage \times MaxAmpere$$

$$Load factor = \frac{AverageLoad}{PeakLoad}$$

$$Loss factor = \frac{Averageloss}{Peakloss}$$

$$Powerloss = 3 \times Imax^2 \times R$$

Considering developed countries, the power loss doesnot deviate by more than 10%. However, the power losses for developing countries is more than 20%. In this network, losses were calculated by simulation. Here, loads are considered as lumped loads for both base loading and peak loading period.

3.2 Voltage Levels

Selection of voltage is the first step in the design of the distribution network. The voltages most commonly used for this purpose are 11 kV and 33 kV. Voltage drop occurs in the power system from source to load point. The voltage drop increases gradually from the sending to the receiving end. It also depends on the line impedance. Poor voltage profile at end of the final consumer is one of the problems in the distribution system feeders.There may be many reasons of poor voltage profile such as using the equipment in under voltage condition below nominal value both at the sending and receiving end especially at Bankul feeder of Gaur substation. Undersizing of conductor at many branches in the feeder network and longer radial feeder length are main reasons to cause low voltage at the ends of the consumer.

3.3 Material considerations

Base case model of the feeders network of Gaur substation uses ACSR (Aluminium Conductor Steel Reinforced). Majority of conductors are Weasel, Rabbit and Dog. Substation unit of total capacity of 8 MVA is considered and injected into Bankul feeder after sectionalizing it into two parts. Table 1 shows conductors library used for Gaur substation feeders.

Table 1: Conductors used on Gaur substation

S.No	Code	Size
1	Weasel	30
2	Rabbit	50
3	Dog	100

4. Results and Discussion

Since all the feeders of Gaur substation are radial in configuration, each feeder is analysed separately. The Single line diagram of the respective feeder is considered and the line data and load data of the feeder is enetered into ETAP. The feeders are studied assuming all the lump load and balanced load flow. For each study case, the software produces detailed accounts of voltage profile, power losses, reactive power flow and power factor on the network. These detailed reports are used to investigate and analyse the overall performance of the distribution feeders.

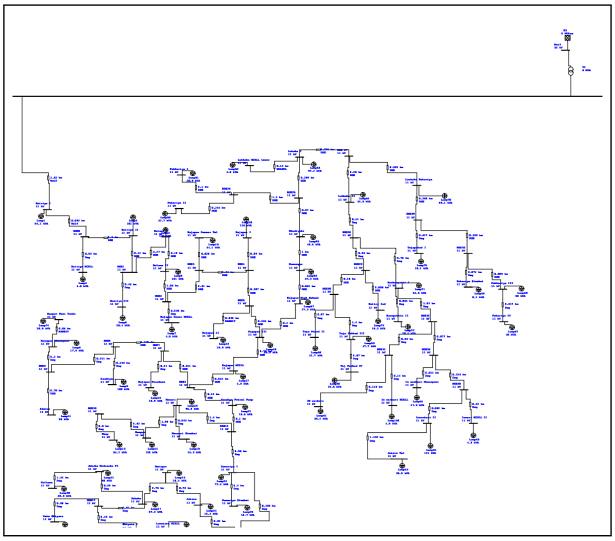

Figure 3: One line diagram of Bairiya feeder

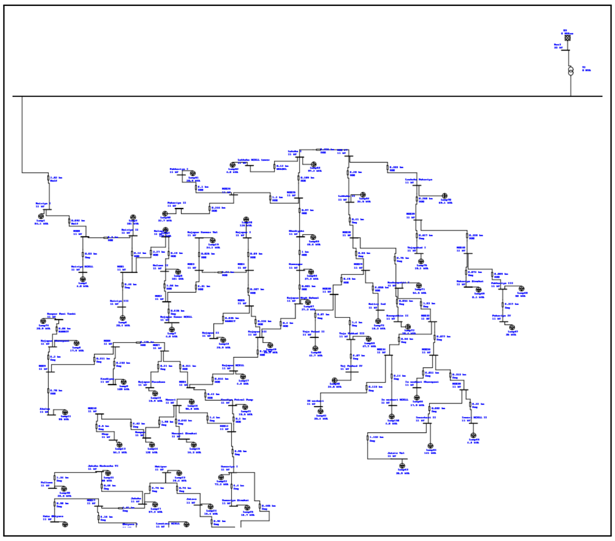

Figure 4: One line diagram of Bankul feeder

The branch total active power loss of the Bairiya feeder is 129 kW, while the active power loss of the Bankul feeder is 339 kW. From peak loading scenario, it is seen that active power loss for Bairiya feeder increases from 129 kW to 391 kW. Similarly, active power loss is increased from 339 kW to 1428 kW for Bankul feeder. From the voltage profile, it is seen that voltage is extremely low below 10 kV and is declined to minimum value of 5 kV for Bankul feeder.

4.1 Solution Techniques

4.1.1 Voltage Improvement

Voltage improvement is considered as one of the main power quality issues. There are various methods to improve the voltage profile such as adjustment of transformer tap setting, sectionalization of the feeder and providing of power from nearest available substation.

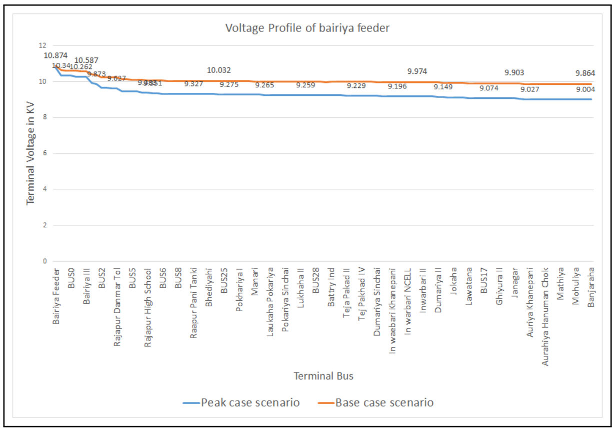

Figure 5: Voltage profile of Bairiya feeder

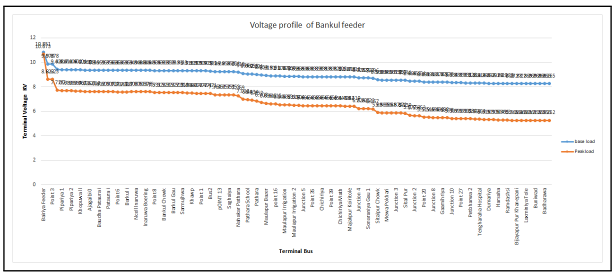

Figure 6: Voltage profile of Bankul feeder

Approach 1: Conductor replacement and transformer tap setting .

One of the methods that can be employed for the improvement of the voltage profile along the feeders is to replace the undersized conductor with higher conductor size and changing the transformer tap setting at higher voltage side. To keep the secondary voltage almost near to 11 kV, either primary voltage or the high voltage tap position of the winding must be altered. To raise V2 from 9 kV to 11 kV, it requires an increase in secondary voltage of 11 kV/10.5 kV = 1.047 N1 and must be reduced to 1/1.047 = 0.95. Therefore N1 must be reduced by (1-0.95)= 5%. All the weasel conductor and rabbit conductor of lower size is replaced by dog conductor of 100 sq.mm.

Approach 2: Sectionalizing the Bankul feeder and supplying power from nearby substation .

Due to very weak configuration and long radial distribution network, Bankul feeder suffers from very low voltage profile. So, it is not economical to install capacitor bank at every load bus bar to improve voltage profile. So, the methods we have used is feeder cut or sectionalization of the feeder and injection of the power from nearby substation at shortest distance point and feeding it with Bankul bus bar.

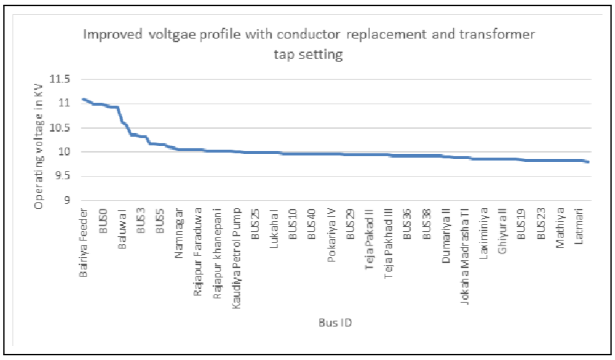

Figure 7: Improved voltage profile after conductor replacement and tap setting

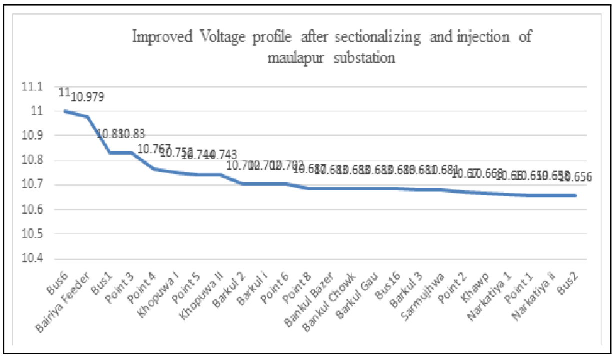

Figure 8: Improved voltage profile Bankul feeder section I after sectionalizing

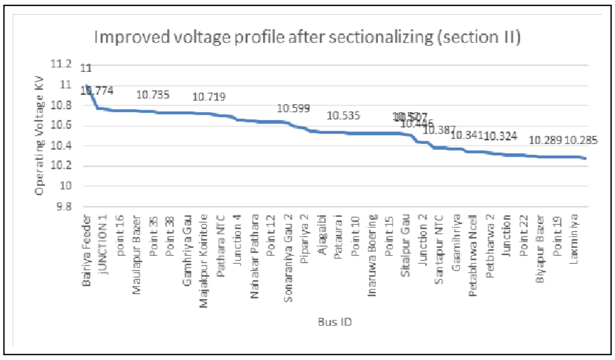

Figure 9: Improved voltage profile Bankul feeder section II after sectionalizing

4.1.2 Power Loss Reduction techniques

4.1.3 Replacing conductor and transformer tap setting

After replacement of all Weasel conductor and rabbit conductor by dog conductor of 100 sq.mm. and adjusting transformer tap settings simultaneously, it is observed that for base case, the total loss is 88 kW. Total power loss for peak loading is recorded to be 329 kW after conductor reconfiguration. Figure 10 shows the overall loss summary of Bairiya feeder. During the peak loading, the total power loss is decreased by 15.85% after reconfiguration of the feeder.

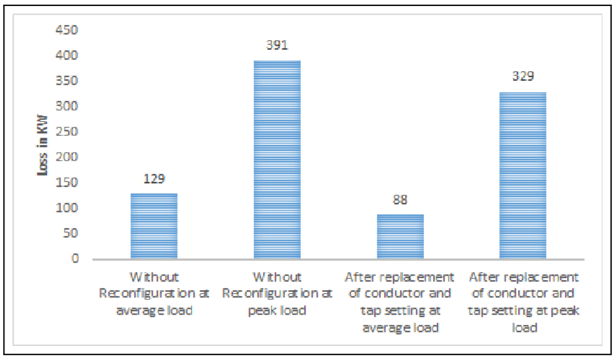

Figure 10: Summary of Power losses for bairiya feeder

4.1.4 After sectionalizing Maulapur substation at optimal bus bar of Bankul feeder

From peak case loading scenario of total loss from section I and section II, the total active power loss is 152.167 kW. Power loss is decreased to 89% after supplying power from Maulapaur substation as it increases the reliability of the network.

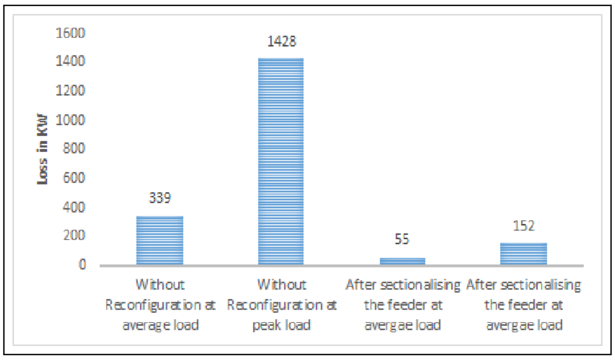

Figure 11: Summary of Power losses for bankul feeder

5. Conclusion And Recommendation

5.1 Conclusion

Poor voltage profile is seen for Bankul feeder and has the minimum bus voltage of 5.25 kV, which violates NEA Grid Code Standard, 2011. From the voltage profile of the Bankul feeder after sectionalizing the feeder into two parts and injecting power from Maulapur substation at the minimum bus voltage, it is seen that the voltage profile is improved for Maulapur substation. The receiving end consumer voltage is measured to be around 10 kV, which is improved from 5.25 kV at peak loading condition. Feeder reconfiguration of Bankul feeder results in improvement of voltage profile from about 47% to 91% of the grid voltage in the bus with minimum voltage. Replacement of weasel and rabbit conductor with dog conductor and transformer tap setting simultaneously in Bairiya feeder improves the voltage profile and reduces the power losses by 62 kW, which shows about 15% reduction in power losses. The active power loss of the Bairiya feeder is 129 kW and 391 kW for base case and peak load condition without reconfiguration respectively. Replacement of the weasel and rabbit conductors with dog conductor and adjustment of transformer tap settings in Bairiya feeder reduces the power losses to 88 kW and 329 kW for base load and peak load respectively. This elucidates saving of 63 kW and 41 kW for Bairiya feeder in peak case and base case respectively. Total power loss for peak loading of Bankul feeder is found to be 152.16 kW, which results in saving of 1275.8 kW for peak case condition. On the other hand, 284 kW power is saved from base case condition after injecting Maulapur substation at Bankul feeder. Total power loss for peak loading is 152.16 kW which results in saving of 1275.8 kW for peak case condition while 284 kW power is saved from base case condition after injecting Maulapur substation at Bankul feeder.

5.2 Recommendation

The voltage profile improvement and power loss reduction of Bairiya and Bankul Feeder can further be performed for performance improvement of the Distribution System Feeder through other techniques like Optimal Capacitor Placement, Injection of Distributed Generation (DG) and even utilization of modern FACTS devices such as D-STATCOM. Reliability assessment of the feeders of 33/11 kV Gaur Substation can be performed. The analysis can further be enhanced considering load growth models in account. The research can be extended for no-load condition that might arise due to sudden load rejection in the feeder. Optimal placement of capacitor banks and feeder reconfiguration simultaneously using algorithm based metaheuristic methods such as Genetic Algorithm, Ant Colony Optimization, Particle Swarm Optimization can be employed to get the most optimal power flow condition for improvement of voltage profile and power loss reduction. Detailed economic analysis can be performed for Bankul and Bairiya feeder for feasibility analysis.

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