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Study of Impact on penetration of induction stoves in electrical distribution network of Jorpati, Kathmandu: A case study of Gothatar Feeder

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Abstract

The use of Induction stoves by replacing traditional ways of cooking can be beneficial for improving the health of people and for reducing impact on environment. Due to this Induction stove is gaining massive popularity in new policies initiated by the government. When there is massive insertion of Induction stove, it can be burden to electrical power distribution network. For our study residential area of Gothatar is taken which is supplied by Gothatar feeder of Jorpati Distribution Center. Gothatar feeder is radial feeder having total length of 10.67 kilometer with Dog, Weasel and Rabbit conductors. Gothatar feeder consist of total 4946 consumers and consisting of 36 public transformers and 13 private transformers. This study analyzes the effect of penetration of induction stove in 11 kV Gothatar feeder of Jorpati Distribution Center using DigSILENT powerfactory software. Electrical distribution networks are surveyed in terms of peak power of feeder, active power loss, line loading, voltage deviation, and transformer loading before and after penetration of Induction stove. For the feasibility of study different zones of area are created for induction stove penetration. At base case peak load is seen at 7 p.m. in the month of Poush which is 5.73 MVA with active power loss of 113 kW. Induction stove is penetrated at various operating range at different zones at step of 5 percent. When the penetration level of Induction stove reached 25 percent power demand reached 7.67 MVA and active power loss reached 179 kW. As induction stove penetration level increases the transformers got overloaded. At 25 percent penetration of Induction stove 18 number of the transformer got overloaded at different sections along with conductors. Analysis of results are performed. The results shows that to increase the withstand capacity of distribution network for induction stove penetration mitigation have to be applied. Mitigation is done by changing transformer, cable, protection system to next higher available standard size for the reliable operation of electrical distribution network.

Keywords

Induction, Penetration, Distribution

1. Introduction

Cooking through electric appliances contribute to suitable time in order to approach for clean cooking. To protect the health of people and reduce impact on environment there is need in change in current cooking methods. This relate to 4 billion people out of which 2.7 billion people have no clean cooking facility and also 1.3 billion people with no proper clean cooking standard. This means that 4 billion people cannot cook effectively, polishedly, favorably, reliably, harmlessly, cheaply [1].

There have been many approaches to improve traditional cookstove, biogas stoves, replacing those with LPG but now cooking through electric have become trend for cooking purpose. This can be opportunity for low income household. Adopting electric cooking is an important approach for sustainable goal achievement for clean cooking practice. Most benefit that can be taken will be by women from electric cooking which is clean, reliable, safe. Government of Nepal is also adoption for the use of Induction stove in their new policies. In budget speech FY 2022/23[2] in article number 252, campaign that was launced was to Quit L.P. Gas, Connect Electric cooking. In which promotion of biogas, electric stoves, improved stoves, and other suitable modern and economical technologies was carried out to substitute firewood, dung cakes and LP gas used as cooking fuel, thereby generating access to clean cooking energy for around 100 thousand households. Policies have been made for providing subsidies on electricity consumption by gradually reducing the subsidy provided in LP gas. Therefore, electric cooking can be transition to sustainable energy to all. The total energy consumption, which was 626 PJ in FY 2020/21, has reached 640 PJ in FY 2021/22. Out of the total energy consumption, the ratios of traditional, commercial, and renewable energy consumption have been 64.17 percent, 28.35 percent, and 2.52 percent respectively FY 2021/22. Also, out of total energy consumption in Nepal, 60.59 percent of energy is consumed in residential sector, 10.49 percent in transportation sector, 22.17 percent in industrial sector, 4.79 percent commercial and 0.49 percent in agricultural sector [3]. As per the NEA fiscal year report 2022/23 the domestic consumer accounts for 92.32 percent from total consumers [4]. This shows that cooking can be main factor for energy consumption. Hence, it can be relatable to check possibility of induction stove in electric power system network. Many programs had been allocated for promotion of induction stove in Nepal. Fourteen thousand induction stove were distributed by smaller programs and twenty five thousand induction have distributed through two large programs via Nepal Renewable Energy Program, and AEPC Terai cookstoves program, have distributed with 500 thousand stoves, can have large-scale impacts in distribution network in the coming years. The study conducted by [5], on Ecuadorian households in prototype house to determine possible effects of induction stove have resulted that induction stove does not create considerable harmonic distortion levels in residential sector. The induction stove shows a better response during the heating process and better energy efficiency than LPG based stoves [6]. Three hundred watts rice cooker can be operated by hundred percent of connected user without exceeding substation capacity. [7]. This research work is mainly focused on effect that hamper the power quality of electrical distribution network in terms of voltage drop, transformer overloading, conductor overloading, power loss, due to penetration of induction stoves in distribution network.

2. Methodology

2.1 Technical Analysis

Technical parameters is evaluted for determining the effect of Induction stove penetration in residential households. Process flow diagram for our research work is shown in figure 1.

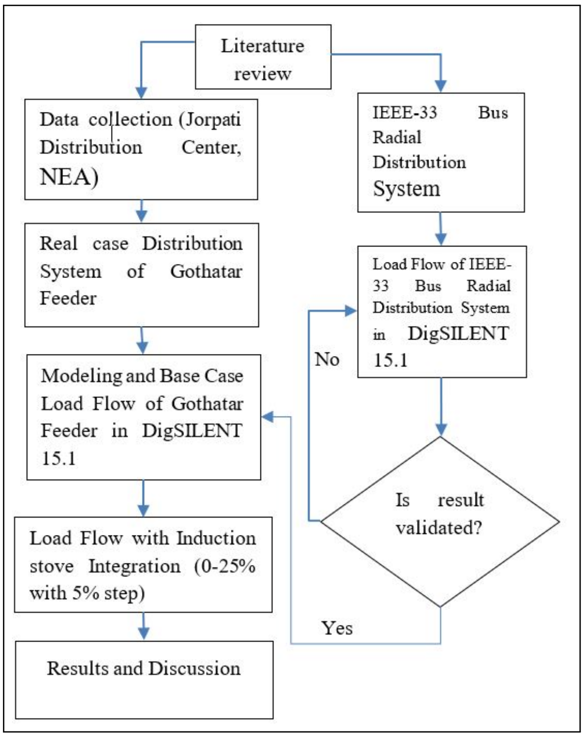

Figure 1: Process flow chart

The work begins with the literature review, where induction stove and its impact on voltage profile of the distribution network is studied when integrated to the existing network. As our study requires residential area for Induction stove penetration so, Gothatar area is choosen. Gothatar area is residential area and the number of consumers are increasing gradually in that area. Supply of power to Gothatar area is provided by Jorpati Distribution Center and feeder that feeds power to that area is Gothatar feeder. So, data were collected from Jorpati Distribution Centre for our research work and Gothatar feeder was selected for study. Gothatar feeder consist of total 49 transformers of different capacities. Out of 49 transformers 13 were private transformers and 36 were Nepal Electricity Authority supplied public transformers for residentail households. For our study public transformers were selected for induction stove penetration. Yearly peak demand in Gothatar feeder is evaluated and it showed that peak demand occured at evening 7 p.m. of Poush month which is 294A. Since, peak occured at Poush month so, load profile of feeder is taken for Poush month. Modeling of distribution network is perfomed in DiGSILENT 15.1 software. Feeder consist to total 49 transformers among which 36 transfrmers are public transformers.Also, length of feeder is 10.67 kilometer and different tree branches are emerged at various sections of buses of feeder so, for feasibility of study Gothatar feeder is divided into different zones of area for induction stove penetration. Creation of zone of Gothatar feeder is shown in figure 2.

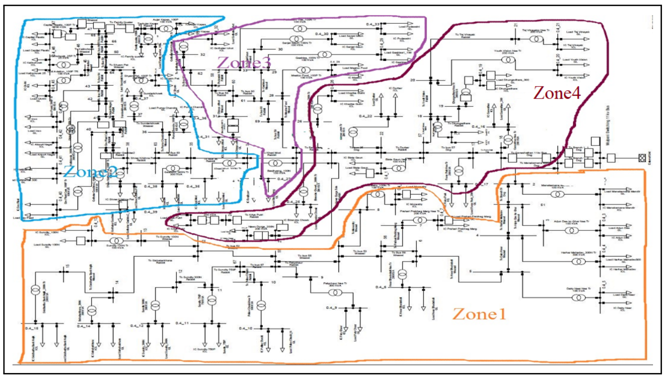

Figure 2: Creation of different zones of area

Load on transformer is considered as lumped load and induction stove in penetrated at low tension side of transformer along with existing load. Four zones of areas are created for Induction Cooktop penetration. Name of such zones of areas are zone1, zone2, zone3 and zone4. In zone1 there are 13 transformers for Induction Cooktop penetration. Similarly, in zone2, zone3 and zone4 there are 8, 9 and 6 transformers respectively. For the purpose of our study, we used 2000 watts induction stove of Baltra company which can operate at maximum of 2000 watts during cooking hour and have frequency of 50Hz, power factor of 0.8. In each areas Induction cooktop are operated at different capacity rating such as 500 watts, 1000 watts, 1600 watts and 2000 watts respectively.

At first base case load flow was done. Load flow with induction stove penetration was performed to existing distribution network at 5 percent interval upto 25 percent. At 25 percent penetration of Induction stove equipment which gets overloaded or not operating normally are upgraded to higher size for reliable operation of distribution network. In order to validate the research work in software load flow is done in IEEE 33 bus radial distribution system.

2.2 Financial Analysis

Initially cost for conductor upgradation and transformer upgradation were determined along with materials required for upgradation. Costing of upgraded transformer size was obtained from Nepal Ekarat Engineering Co. Pvt. Ltd. The labor charge is determined from district rate of Kathmandu district and Nepal Electricity Authority.

3. Results and Discussion

3.1 IEEE-33 bus distribution system

Load flow analysis of standard IEEE-33 bus RDS was performed and results were analyzed. Power loss of the system was found to be 210 kW and the minimum voltage was found at bus 17 and 18 which was 0.90400 pu. The data obtained were validated with [8] and [9].

3.2 Base case scenario

Load flow was performed of Gothatar feeder at base case condition. Total peak demand was obtained to be 5,730 KVA and total active power loss was found to be 113 kW. There were total 67 buses in Gothatar feeder. Highest bus voltage was 1 p.u. seen at source bus and minimum voltage was 0.975113 p.u. seen at bus 49. Due to short line length no voltage violation was obtained initially. Two transformers naming Tr-5 is operating at 106 percent and Tr-2 is operating at 101 percent at zone1 and remaining transformer at all zones were operating normally along with zone1. Conductor naming To Harhar Mahadev was operating at 101 percent and all other conductors are operating normally in all the zones. The loading of feeder at base condition is shown in figure 3:

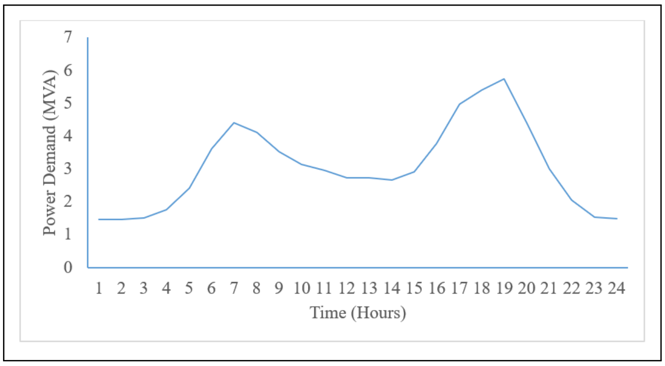

Figure 3: Load profile at base case scenario

3.3 Induction stove penetration

Induction stove of 2000 watts of prestige company[10] was used for penetration at each household of electrical distribution network. For induction stove penetration public consumers were taken. Total consumers connected in feeder were 4946 numbers. It is considered that one consumer uses one induction stove. Since, consumers does not uses Induction stove at same capacity so, different operating capacity was considered from 500 watts, 1000 watts, 1600 watts, and 2000 watts. Also, Induction stove was penetrated at different zones of existing electrical distribution network at the step of 5 percent. In our study we penetrated Induction upto 25 percent level. At 25 percent penetration of induction stove loading on feeder was increased from 5730 kVA to 7670 kVA and active power loss was increased to 179 kW. Lowermost voltage was seen at bus 49 which is 0.967395 p.u. Loading of feeder after induction stove penetration is shown in figure 4.

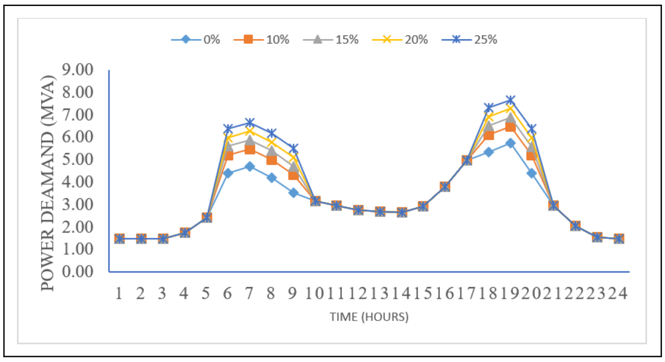

Figure 4: Feeder loading after induction stove penetration

Due to short line length no voilation in voltage was seen in feeder even after the induction stove penetration. The voltage profile of feeder is shown in figure 5.

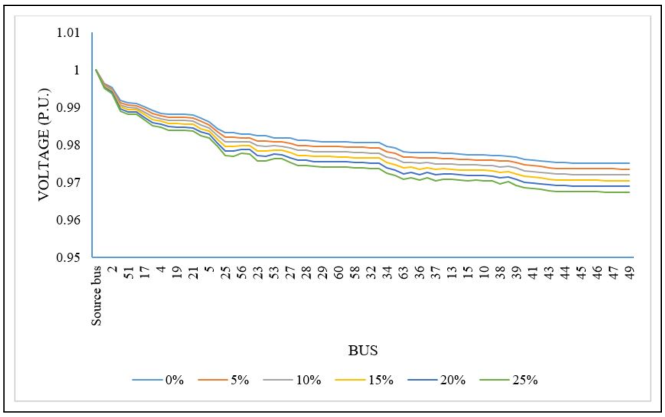

Figure 5: Overall voltage profile after penetration

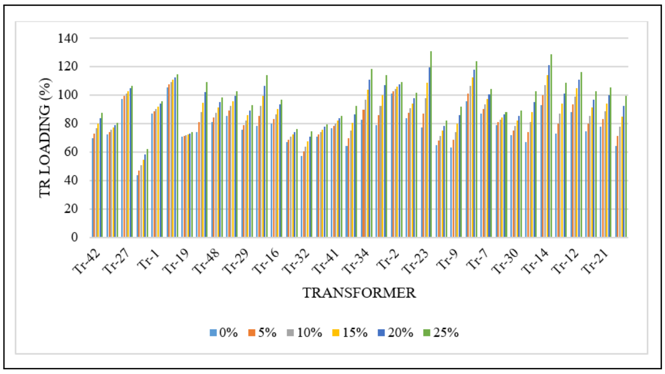

Figure 6: Overall transformer loading before mitigation

When the Induction was penetrated, the voltage started to get reduce at different bus. At different level of penetration, no any voltage violation was observed. Initially lowest voltage was seen at bus 49 which is 0.975113 p.u. which reduced to 0.967395 p.u. at 25% penetration level. At 25% penetration of

Induction stove at zone1 eight transformers were overloaded and at zone2, zone3 and zone4 three transformers were overloaded at each of the zones. The overall transformer loading of transformer in feeder is shown in figure 6.

Initially, Tr-5 and Tr-2 were overloaded at base case condition. As the penetration of Induction Cooktop increases the loading of transformer is increased. At 10% penetration of Induction cooktop additional Tr-10, Tr-14 and Tr-27 were overloaded. At 15% penetration of Induction Cooktop additional Tr-34, Tr-24, Tr-23 and Tr-12 were overloaded. At 20% penetration of Induction Cooktop additional Tr-22, Tr-35, Tr-7, Tr-13 and Tr-21 were overloaded. And at 25% penetration total of transformer that were overloaded are Tr-5, Tr-2, Tr-10, Tr-14, Tr-27, Tr-34, Tr-24, Tr-23, Tr-12, Tr-22, Tr-35, Tr-7, Tr-13, Tr-21, Tr-17, Tr-15 and Tr-37 were overloaded. The result shows that we have to increase the size of transformer. Since, in our study we opt for condition of distribution at 25% penetration of Induction Cooktop. We have to replace the transformer by their next higher size for reliable operation of system.

The loading of conductor is shown in figure 7. As shown in figure 7, conductors from bus 51 to 4, bus 4 to 5, bus 5 to 6, 5 to 56 and bus 57 to 22 are overloaded.

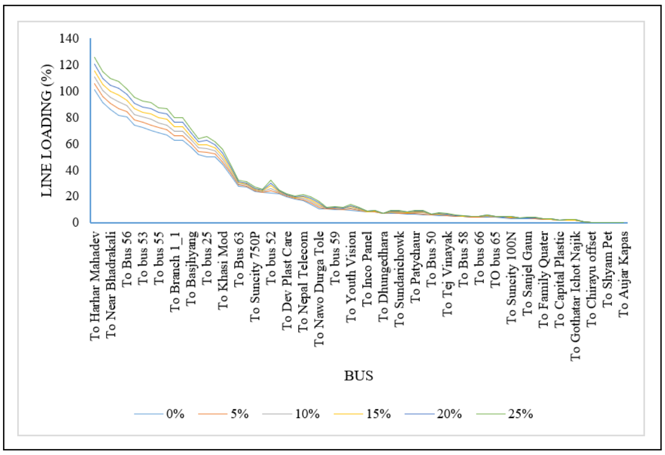

Figure 7: Overall loading of line

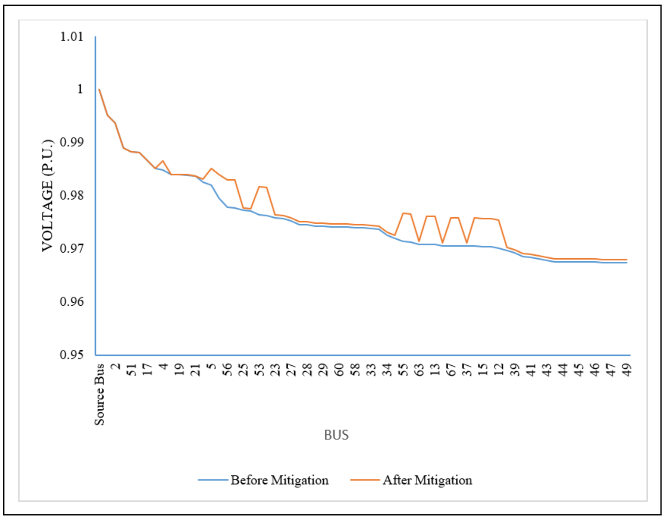

Figure 8: Voltage profile before and after mitigation

So, mitigation is applied for these overloaded transformers and conductors. For mitigation purpose first of all transformers and conductors which were overloaded were determined. Then next standard size transformers and conductors available in market were used for upgradation. Total 18 transformers were to be upgraded and conductor of total length 3161 meters were upgraded next higher size.

Voltage profile of feeder after mitigation is shown in figure 8. After mitigation it is seen that voltage of buses are increased. Lowermost voltage seen at bus 49 which was 0.967395 p.u. was increased to 0.967958 p.u.As no voltage violation was seen in buses even after the penetration of Induction Cooktop due to short length of line.

Loading of transformer after mitigation is shown in figure 9.

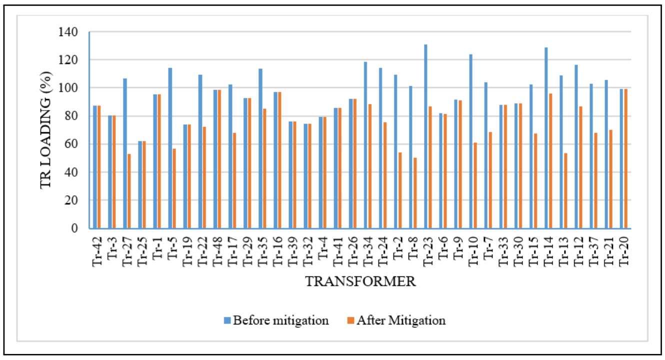

Figure 9: Overall transformer loading before and after mitigation

After mitigation loading of Tr-5 was reduced from 114% to 57%, Tr-2 was reduced from 109% to 54%, Tr-8 was reduced from 102% to 50%, Tr-10 was reduced from 124% to 61%, Tr-7 was reduced from 104% to 69%, Tr-15 was reduced from 103% to 68%, Tr-14 was reduced from 129% to 96%, Tr-13 was reduced from 108% to 54%, Tr-12 was reduced from 116% to 87%, Tr-35 was reduced from 114% to 85%, Tr-34 was reduced from 118% to 89%, Tr-37 was reduced from 103% to 68%, Tr-27 was reduced from 107% to 53%, Tr-24 was reduced from 114% to 76%, Tr-23 was reduced from 131% to 87%, Tr-22 was reduced from 109% to 72%, Tr-17 was reduced from 103% to 68%, and Tr-21 was reduced from 106% to 70%. Similarly, loading of conductor after mitigation is shown in figure 10.

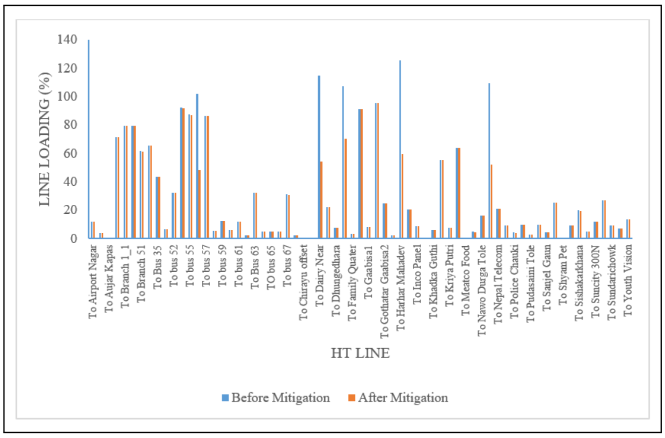

Figure 10: Line loading before and after mitigation

It is seen that at 25% penetration loading of line To Harhar Mahadev was reduced from 125% to 59%, To Dairy Near was reduced from 114% to 54%, To Near Bhadrakali was reduced from 109% to 52%, To bus 56 was reduced from 102% to 48% and To Durbar was reduced from 107% to 70%.

At 25 percent level penetration of Induction stove mitigation was proposed. During mitigation 18 transformers were changed and conductor of total lenght 3161 meter was changed to next higher standard size. Costing of 18 transformers and conductor is performed. It is found that total cost for conductor upgradation is accounts to Rs. 741,050.92 and total cost for transformer upgradation is Rs. 15,132,411. Total investment required for ensuring 25 penetration of induction is Rs. 1,58,73,461.92.

4. Conclusion

Initially the loading feeder was 5730 kVA with active power loss of 113 kW. At twenty five percent penetration of Induction stove the loading of line increased to 7270kVA and active power loss was increased to 179 kW. No voltage violation was seen at any zones of different penetration level of induction stove. Twenty transformers out of thirty-six transformers where overloaded so, upgradation have to be made and total line length of 3161 meter have to be upgraded. After upgradation of transformer and conductor distribution line can be operated smoothly. Active power loss was reduced from 179 kW to 170 kW. Total invest to be made for reliable operation is Rs. 1,58,73,461.92.

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