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EVALUATION OF WHEELING CHARGE IN CONTEXT OF NEPALESE POWER MARKET

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Abstract:

In case of power system operating under deregulated environment, there will be a transmission company whose major task is to construct, own and operate the transmission system. On evacuating the powers, it charges wheeling charge to the user. However, it should be ensured that the wheeling charges paid by the user must be fair and accurate. The wheeling charge in context of Nepalese power market is evaluated considering the transmission line of three different voltage levels 132 kV, 220 kV, and 400 kV. Annual operation and maintenance cost of 1% of capital cost is also considered to evaluate the wheeling charge. In order to charge the user fairly, wheeling charge in context of Nepalese power market considering the Integrated Nepal Power System of year 2040 is evaluated (i) without considering transmission losses (ii) considering the transmission losses (iii) considering power factor of 0.8 and (iv) considering the power factor of 0.9 for reference power factor of 0.85.

Keywords: *INPS, Wheeling Charge, MW-mile Method, Power factor correction term*

1. Introduction

In the Nepalese power market, while there is competition in the generation sector, the transmission and distribution sector is still under a monopoly controlled by the Nepal Electricity Authority (NEA).

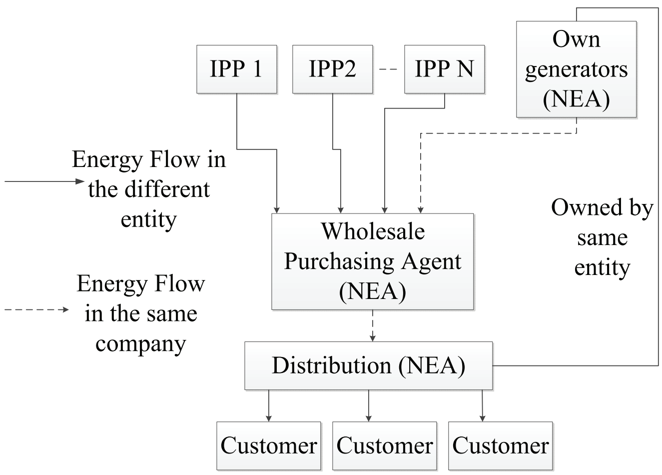

Figure 1: Vertically Integrated model of Nepalese Power System

However, on July 15, 2015, as part of the NEA unbundling process, the Government of Nepal established a distinct transmission entity named Rastriya Prasaran Grid Company. This company's primary purpose is to handle the transmission and evacuation of power for the advancement and operation of the hydropower sector, while the distribution aspect will remain under the purview of the Nepal Electricity Authority [1]. This transmission entity facilitates trade between the generation and distribution sectors, and it will play a crucial role in reshaping the power industry within the country. Power transmission is an area where economies of scale hold significant importance, leading to potential monopolistic tendencies in the system. The parameters that define the electric power transmission sector include [2].

a. Substantial, fixed capital investments

b. Necessity for redundancies to fulfill security standards

c. Economics of scale in building expenses relative to the transmission line’s capacity.

d. Economics of scope enabled by the integration of the electrical system.

Therefore, to avoid excessive charges from transmission utilities, it is essential to have regulatory oversight over the transmission system. This becomes especially crucial when the transmission system serves as the primary component for transporting power from various generators to the end user. The transmission utility must recoup all expenses associated with building and running the transmission system, along with any essential services.

As we know the electricity demand is increasing day by day and demand is met by power generated through different hydro powers and by importing electricity from India. There is still a monopoly in the transmission market in Nepal. Though there is competition in the generation market, monopoly still exists in transmission and distribution market. To make the transmission system more reliable, efficient and affordable it is necessary to restructure the power market of Nepal. Government of Nepal has formed Rastriya Prasaran Grid Company Limited that performs all the works related to transmission systems only. Therefore, as the volume of energy transactions grows, the requirement for a distinct entity to oversee the transmission system becomes evident. This entity must effectively manage funds for the construction and optimal operation of transmission lines. To ensure the entity's sustainability, it must recoup the invested costs, with the primary source being the wheeling charge.

In case of Nepal, studies were done for the evaluation of wheeling charge using MW-mile method. Evaluation of wheeling charge without considering the transmission line loss but it is not fair to charge the user without considering the transmission line loss. For this following three cases are considered:

Case I: When a user at the receiving end operates their load at the specified reference power factor, they will be charged based on the effect of power flow during the transaction, but any losses are not taken into account. To compensate for these losses, the generator must produce and deliver extra power equivalent to the losses, for which the generator receives no compensation.

Case II: If a user at the receiving end operates their load at a power factor below the designated reference level, they will be charged based on the influence of active power flow during the transaction. The transmission capacity diminishes due to increased loss, stemming from the need for additional reactive power supplied by the generator to offset the loss, which often goes unaccounted for.

Case III: When a capacitor bank compensates for the load at the receiving end, it enhances transmission capacity and reduces losses. This means the generator doesn't need to supply as much extra power compared to the previous scenario. In this situation, the user should receive recognition or benefits, which is often overlooked.

2. Literature Review

Various studies have been done in other countries to evaluate the wheeling charge. In South America [2] Open access for the transmission pricing scheme is practiced. Similarly, Shirmohammadi [5] describes the basic technical concepts involved in developing cost-based transmission prices and example of its application for pricing transmission services in Brazil.

Similarly, Study done by Sushil Aryal and Nava Raj Karki [3] shows that Mega Watt Mile method can be used to determine the transmission pricing in context of deregulated market of Nepal.

N. H. Radzi, K. Iskandar, M. N. Abdullah, M. S. Kamaruddin, S. A. Jumaat and R. Aziz had implemented a cost reflective network pricing and modified cost reflective network pricing methods for allocating the transmission service charges to the transmission user [6].

Study done by Hugh Rudnick, Rodrigo Palma and Jose E. Fernandez [7] shows application of Marginal Cost Based Pricing in the Chilean Power System and difficulties faced in allocating the supplement among parties involved.

Cost Reflective Network Pricing (CRNP) and Modified Cost Reflective Network Pricing (MCNRP) method for transmission services is studied for pricing the transmission charge for Australian National Electricity Market [8].

Study done by K..L. Lo, Mohammad Yusri Hassan [9] shows the negative flow sharing approach allocate transmission transaction charges among users of transmission service. The approach uses the properties of Mega Watt- Mile method but takes into account the economic benefits of both trading parties by analyzing their shares in negative power flow or counter flow.

Study done by A.R Abhyankar and S. A. Khaparde [10] on western regional grid of India suggest a new way that attempts to compute fixed cost allocation of the transmission network. This study suggests a tracing compliant modified postage stamp allocation method that computes a traceable solution that minimizes overall deviation from the postage stamp allocation.

E.T Fasina, B. Adebanji, A. Abe, and I. Ismail [11] proposed an approach for evaluating the wheeling charge in a deregulated power network. This study proposed a hybrid combination of the MVA-kilometer and the Short-Run Marginal Cost (SRMC) method that used power flow and optimal power flow (OPF) analysis to determine the individual participant’s impact on the transmission power flows for the wheeling cost allocation.

Shaik Riyaz, Ramanaiah Upputuri and Niranjan Kumar [12] proposed a Mega Watt – Mile Method that considering the transmission losses and load power factor variation so that the recipient who operates their load at improved power factor gets benefited and the recipient who operates their load at poor power factor gets penalized. This study has been done for IEEE 30 bus system.

R. Gnanadass and N.P Padhy [13] had proposed an improved approach for the allocation of the transmission service embedded cost using the average revenue requirement of the facility instead of the line length as used in the conventional approach. The study justified that the transmission pricing could be computed taking into account the cost of transmission facility due to the wheeling transactions instead of the length of the lines.

Study done by Shuvam Sahay, Niranjan Kumar and Himani Joshi [4] shows how the transmission losses and power factor of the load affects the transmission charges by the case study of IEEE 30 bus system using MW-mile method. This study provides the comparison of the transmission charges by incorporating transmission losses considering the power factor with the cost without considering the transmission loss and the power factor.

Study done by D. Avinash and B. Chalapathi [14] provides a new approach using Mega Watt- Mile Method that evaluates the transmission pricing considering the cost component of loss and power factor.

Similarly tracing based point-of-connection tariff structure [15] is studied for Indian Power System which can be employed for both power exchange and bilateral trades.

Study done by Muhamad Zulkifil Meah, Azad Mohamed, and Salleh Serwan [16] shows the comparative analysis of transmission cost allocation using MW- Mile Method in case of Malaysian Power system. This study compares absolute, reverse, dominant and extended methods on the Malaysian Power system in order to assess their impact on the long-term transmission planning.

Study done by Syarifuddin Nojeng, Mohammad Yusri Hassan, Dalila Mat Said, Md. Pauzi Abdullah, and Faridah Hussin [17] shows an improved MW- Mile Method by considering not only the changes in MW flows but also the power factor of the load. The study was done on IEEE 14 bus system.

Deep Kiran, A.R Abhyankar, and B. K. Panigrahi [18] had proposed a novel concept to club the nodes into zones that are closely connected and experience similar usage prices, for equivalent bilateral exchange, marginal participation method and hybrid method of transmission pricing mechanism. Study was done for IEEE 118 bus system.

Load Flow Analysis

Load flow analysis are used to validate and check the operation of system under normal or outage conditions to see if the system is capable to supply the planned additional loads and compare new alternatives for system additions to supply the new loads or improve the system. Load flow analysis mainly deals with the four quantities of the power system. They are:

a) Voltage magnitude
b) Phase angle
c) Active power
d) Reactive Power

Load flow analysis is performed to validate whether the abovementioned power system quantities are within the limit or not.

Evaluating Pricing Methods

Among various methods postage stamp method and power flow-based megawatt -mile method will be used.

Postage Stamp method

This pricing method evaluates the transmission transaction price according to the amount of the power transacted which is usually measured at the time of the system's peak. This is the simplest method of evaluating transmission pricing. This method does not deal with the transactions with regard to the power flow path, supply or delivery points or the time when it takes place.

It is calculated as[3]:

$$R_t = TC \frac{P_t}{P_{peak}} \tag{1}$$

Where,

R_t is the transmission pricing for transaction

TC is the total transmission cost

P_t is the total power transacted at the time of system peak in MW

P_{peak} is the System Peak in MW

Contract Path Method

The contract path method finds its origins in the days when the electricity supply industry consisted mostly of vertically integrated utilities and energy transactions were infrequent. In this method, a contract specifies an electrically continuous path (the contract path) along which the power is assumed to flow from generator to the point of delivery. The producer and the consumer agree to pay for the duration of the contract a wheeling charge proportional to the amount of power transmitted. This wheeling charge provides part of the revenue that the utility needs to recover the cost of the transmission assets included in the contract path.

Megawatt (MW) Mile method

Two limitations of postage stamp method i.e., power flow on the specific lines and the distance of the transaction (and the losses), are addressed in the MW-mile method. The power flow-mile on each transmission line is calculated by multiplying the power flow and distance of the line. Then the total power flow-mile is then the sum of all the power flow-miles. This total power flow-mile is proportional to the transmission usage and the price is then proportionate to the transmission usage by the transaction.

3. Research Methodology

The study is conducted on the Integrated Nepal Power system (INPS) for year 2040 [1]. The load flow analysis is performed on the INPS and the on the basis of the power flow in the line, capacity of the line and the cost of construction of transmission systems and annual operation and maintenance cost of transmission system the wheeling charges are evaluated using MW-mile Method. At first the wheeling charge is evaluated using equation (1).

In equation (1) the transmission line loss is not considered. Considering the transmission line losses the equation (1) can be modified as [4]:

$$C_k = \sum_{i=1}^{N} \frac{L_{ij} C_{ij} (P_{ij}^k + P_{lij}^k)}{P^k} \tag{2}$$

Where,
P_{lij} is the transmission line losses from bus i to j.
If the effect of variation in the power factor of the load is considered, equation (2) can be modified as:

$$C_k = C_{LF} \sum_{i=1}^{N} \frac{L_{ij} C_{ij} (P_{ij}^k + P_{lij}^k)}{P^k} \tag{3}$$

Where,
C_{LF} is the power factor correction term and it is expressed as :

$$C_{LF} = 1 + \left(\frac{Cos\theta_{ref} - Cos\theta_{act}}{Cos\theta_{avg}} \right) \tag{4}$$

As power factor varies all the time above equation (4) cam be modified as:

$$C_{LF} = 1 + \left(\frac{Cos\theta_{ref} - Cos\theta_{avg}}{Cos\theta_{avg}} \right) \tag{5}$$

Where,

$Cos\theta_{ref}$ is the reference power factor as per the contract

$Cos\theta_{avg}$ is the average power factor of the load

The load flow study for Nepal's Integrated Power System in 2040 projects a 7.2% annual load growth [19]. The study further explores scenarios where the total electricity produced from the Karnali and Arun river basins is exported to India. For each scenario, the wheeling charge is initially determined without factoring in transmission line losses. It is then recalculated with transmission line losses considered, using a reference power factor of 0.85. Finally, the wheeling charge is assessed at power factors of 0.8 and 0.9

4. Results and Discussion

The study is performed on the Integrated Nepal Power System 2040. The total cost of the transmission system is assumed to be the present value of the network cost and then the present value will be annuitized for 17 years (i.e., up to year 2040) at a discounted rate of 10% per annum [19].

The bus voltages of the systems for year 2040 is given as:

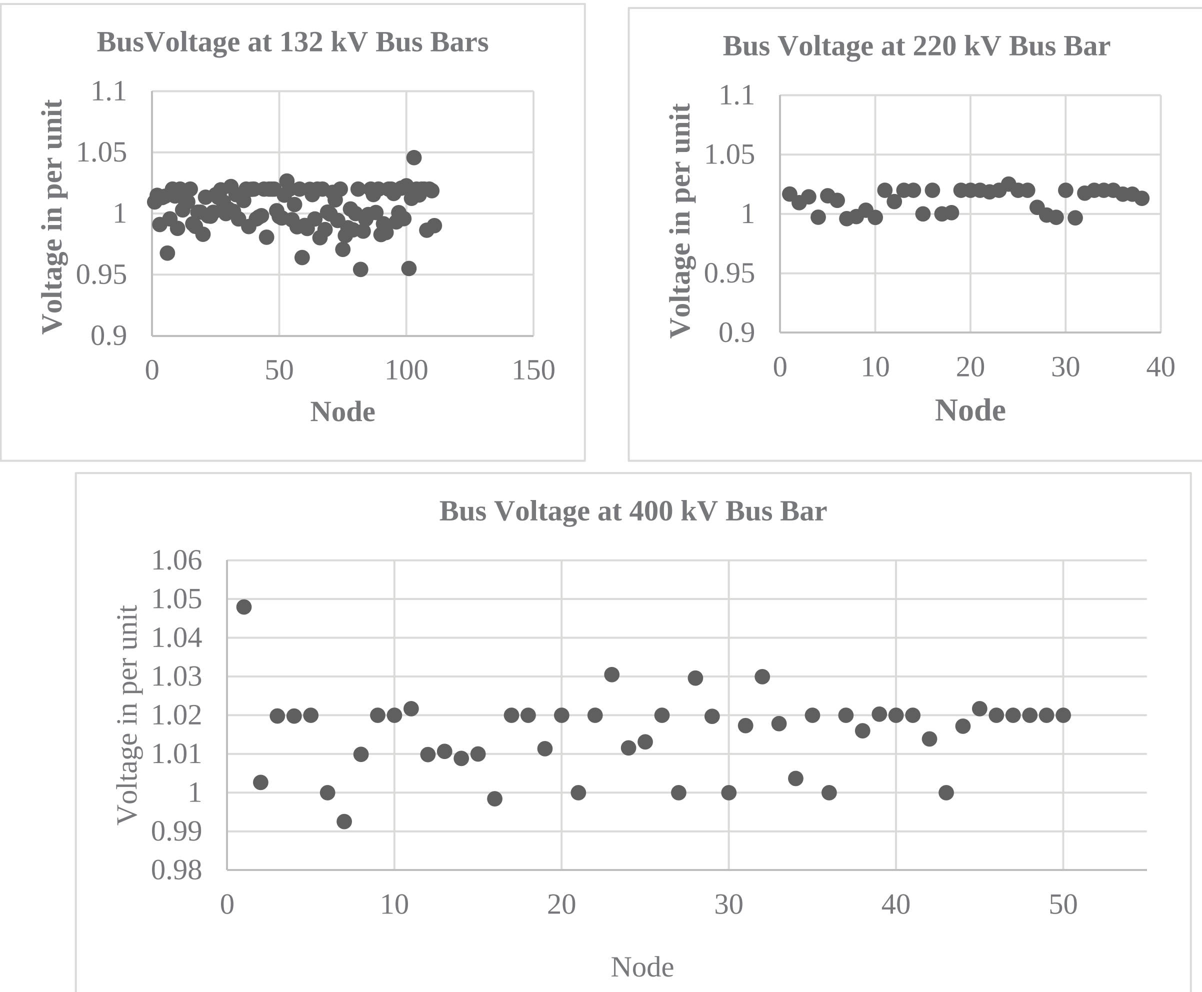

Figure 2: Voltage at 132 kV, 220 kV and 400 kV Bus Bars

From the load flow analysis it was found that the voltages in the 132 kV, 220 kV and 400 kV bus bars were within the prescribed limit i.e. between 0.95 per unit. to 1.05 per unit.

To evaluate the wheeling charge, per mile cost were taken from [1] and the annual operation and maintenance cost is assumed to be 1% of the capital investment. Then unit cost of transmission line is evaluated as the sum of the annuitized cost and annual operation and maintenance cost.

Following scenarios are considered for evaluating the wheeling charge in context of Nepalese Power Market

a. Considering INPS 2040

Considering the load growth of 7.2% [20], it is expected that maximum domestic load at the year 2040 will be 18 GW. For this scenario, the wheeling charge obtained for some of the lines are shown in the figure 2 below. It is assumed that the reference power factor is assumed as 0.85 and the effect of variation of power factor of load on wheeling charge is analyzed.

From figure 3, it is seen that the wheeling charge evaluated considering the transmission line loss is greater than that evaluated without considering the transmission line losses. The evaluated wheeling charge signifies that it encompasses the additional power that the generator needs to produce.

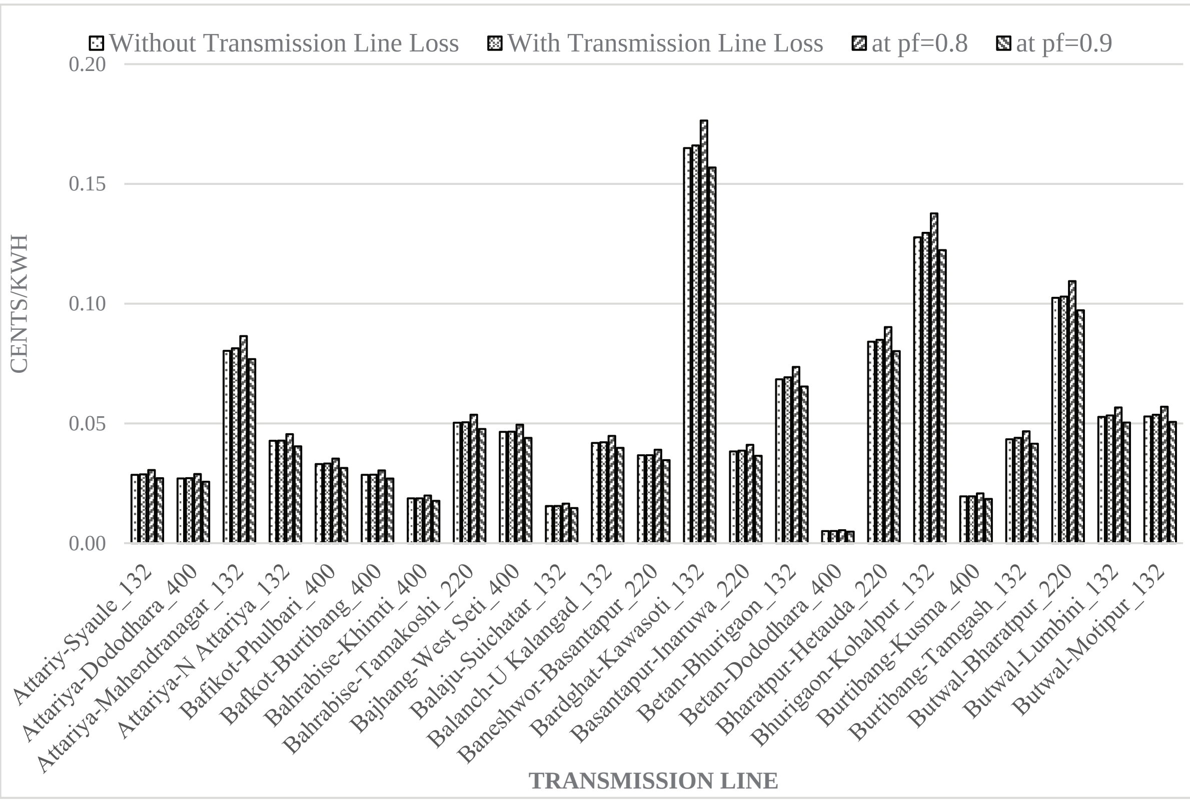

Figure 3: Wheeling Charge for INPS 2040 considering load growth of 7.2%

Furthermore, if the user operates the load at a reduced capacity, or at a power factor lower than the specified reference power factor, they will incur higher charges. This is evident in figure 3, indicating a penalty for the user for operating at a lower power factor. On the other hand, if the user operates the load at a power factor greater than the reference power factor, the wheeling charge is lower. This is illustrated in figure 3, showing a reward to the user for operating at an enhanced power factor.

b. Considering all the hydropowers produced from Karnali River basin to India

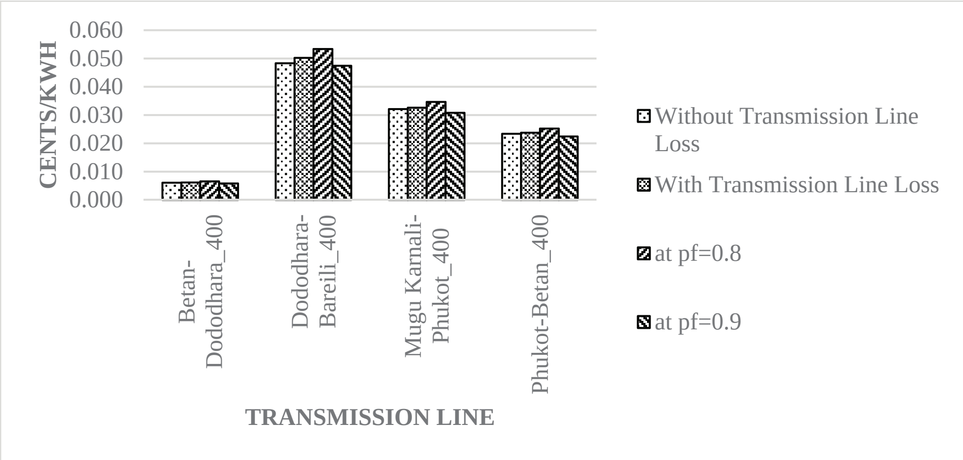

Figure 4: Wheeling Charge when all the powers generated from Karnali river basin is exported to India

All the powers generated from Karnali river basin are exported to India using Mugu Karnali - Phukot 400 kV transmission line, Phukot-Betan 400 kV transmission line, Betan-Dododhara 400 kV transmission line and Dododhara (Nepal)- Bareili(India) 400 kV Transmission line. Figure 4 shows the wheeling charge of the transmission line used for exporting powers to India. Thus, it is seen that the wheeling charge evaluated considering the transmission line loss is greater than that evaluated without considering the transmission line losses. This wheeling charge evaluated indicates that the additional power that generator shall produce is included. Also, when the user operates the load at lower power factor than the reference power factor, the user is charged more which can be seen in the figure 4 as an indication of penalty for user for operating the load at lower power factor. When user operates the load at the power factor greater than that of the reference power factor, the wheeling charge is less as shown in figure 4 as an indication of reward to the user for operating the load at improved power factor.

c. Considering all the hydropowers produced from Arun River basin to India

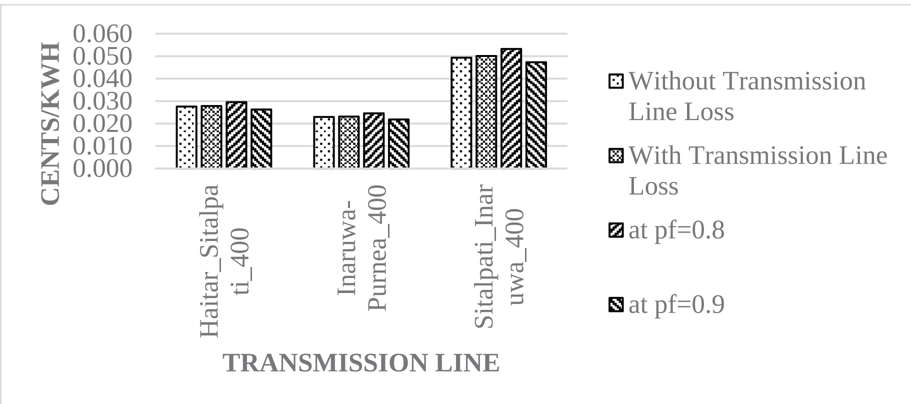

Figure 5: Wheeling Charge when all the powers generated from Arun river basin is exported to India

All the powers generated from Arun river basin are exported to India using Haitar-Sitalpati 400 kV transmission line, Sitalpati-Inaruwa 400 kV transmission line, and Inaruwa (Nepal)- Purnea(India) 400 kV Transmission line. Figure 4 shows the wheeling charge of the transmission line used for exporting powers to India. Therefore, it is observed that considering transmission line losses results in a higher wheeling charge compared to that evaluated without accounting for these losses. This evaluated wheeling charge encompasses the extra power that the generator must generate. Likewise, when the user operates the load at a reduced capacity or at a lower power factor than the specified reference power factor, they incur higher charges, as illustrated in Figure 5, indicating a penalty for the user for operating at a diminished power factor. Conversely, if the user operates the load at a power factor greater than the reference power factor, the wheeling charge is lower, as depicted in Figure 5, indicating a reward to the user for operating at an improved power factor.

5. Conclusion

The wheeling charge evaluation for the Integrated Nepal Power System (INPS) in 2040, within a deregulated environment, considers three scenarios: one that ignores transmission line losses, one that includes them, and a third that accounts for both losses and changes in power factor. The analysis shows that incorporating transmission line losses leads to an increase in the wheeling charge. A reference power factor of 0.85 is used, and the wheeling charge is calculated for power factor deviations, specifically from 0.85 to 0.8 and 0.85 to 0.9. When a user operates at a lower power factor than the reference, their wheeling charge increases, acting as a penalty. Conversely, if the user improves their power factor, for instance by using a capacitor bank, their wheeling charge decreases, providing an incentive for maintaining a higher power factor. Therefore, it is fair to evaluate the user's charge by considering both transmission line losses and power factor variations.

6. Recommendations and Suggestions

Study for the evaluation of wheeling charge is done for the absolute power flow of the INPS model. Still the study needs to be done for the following cases in the INPS model.

i. Dominant power flow
ii. Reverse power flow

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