Price allocation of transmission line usage in open access system using mega volt ampere kilometer and mega volt ampere cost method for integrated Nepal power system

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Abstract. The price allocation of transmission line usage for an open access system considering Integrated Nepal Power System (INPS) has been discussed in this paper using the MVA (mega volt ampere) - KM (kilometer) and MVA cost method. The price allocation has been compared for INPS (Integrated Nepal Power System) and IEEE 14 bus system. The transmission line costs in IEEE 14 bus system is based on average construction and operation cost whereas, the costs in the INPS is an actual cost of the present transmission system. The price has been first calculated for different bus with reference to slack bus and for different bilateral and multilateral transactions, using MW KM - MW cost and MVA KM - MVA cost methods. The active and apparent powers for the base case and transaction cases have been calculated using Newton Raphson Method. The prices from MVA KM - MVA cost method are higher than MW KM - MW cost method for both bilateral transaction and multi-lateral transaction indicating more reactive power support in addition to the real power loading due to transactions in the system. The result shows that MVA KM - MVA cost method requires incentives for reactive power support to the system such as INPS.

Keywords: Integrated Nepal Power System, MVA-KM, MVA Cost.

1. Introduction
In a competitive electricity market, there is always a demand for efficient transmission pricing that recovers the transmission cost due to the proper allocation of the price for the several transmission service users. In a vertically integrated environment, public enterprises are responsible for the generation, transmission and distribution of electrical power in a given geographical area [1]. An open market provides stronger incentives to the supplier to apply cost-minimizing procedures than a regulated market [1]. The transmission tariff structure should be such that it covers the embedded cost, future expansion
cost and the operating cost. Embedded costs in the transmission are huge as compared to other operating costs, so the pricing structure should be very efficient to recover the cost from all its users. In [2], the author has discussed basic concepts and issues regarding the transmission pricing in a vertically integrated unit and have shown that the transmission pricing is one of the most critical and vital issues in the power system. Reactive power flow can affect the line losses and voltage magnitude when customer loading is heavy. It can also push up bus voltages, change tap settings of transformer, load circuit to their limits or bring circuit off limits when oppositely oriented. [3][4]. Increasing reactive power production nearby of the load center can sometimes improve transmission constraints and allow cheaper real power to be delivered to the load. The pricing of the reactive power will provide incentives to efficiently site reactive power devices [5]. Nepal’s electricity market has been a vertically integrated monopoly under Nepal Electricity Authority (NEA) owning generation, transmission and distribution. However, initiations are being undertaken for unbundling NEA with formation of separate transmission company. Nepal has been importing its deficit power through cross border power trade from India. The power trade between neighboring countries and power flow within restructured Nepal’s power market will require transmission open access and proper transmission pricing. So, the concept of reactive power pricing has been discussed based on MVA KM and MVA cost methods considering transmission open access of regulated Nepalese electricity market.

2. Methodology

In this paper, the calculation of transmission usage in open access system is considered for the IEEE 14 bus system and INPS by using MVA KM and MVA cost method. The price allocation is based on the flow at each circuit that is caused by the generation or load pattern of each agent bases on active and reactive power flow. Embedded cost of transmission facility is allocated based on changes in power flow caused by a transaction in a transmission line and length of the line. The load flow study on both the cases (IEEE 14 bus and INPS) is performed by using Newton Raphson Method. Power System Analysis Toolbox (PSAT) tool is used as simulation tool for the load flow analysis. Cost of transaction is identified with respect to the base case for both systems. The power flow analysis is performed to analyze the base case and base power flow from which a base transmission charge of each line is identified. The transaction cost is identified by using

\[
C_{MT} = \frac{C \cdot \sum \Delta(MVA_f)}{8760 \cdot \sum \Delta(MVA_f)}
\]

where,

\( MVA = MVA_{T} \) (with T) − \( MVA_{T} \) (without T)

\( C_{T} \) cost of transmission facility f

\( \Delta MVA = (MVA_{T})_{T} \) is MVA flow in facility f due to transaction,T

The analysis is performed with base case, bilateral transactions and multi-lateral transaction for both IEEE 14 bus and INPS System. Different assumptions were made for the price allocation of the transmission line during analysis in IEEE standard bus system. The investment cost for the transmission system is derived from the average cost for transmission line development in Nepal where,

Per Km Line Cost for the 132 kV Line = ($88,253.3)

Per Km Line Cost for the 33 kV Line = ($39,215.7)

Annual operation and maintenance cost of transmission line is considered as 1.5% of total cost of investment, whereas life of transmission line is considered as the 35 years as Build, Own, Operate and Transfer BOOT model of license of Nepal. The costs associated with transmission line have been derived as:
Annual Cost of Transmission Line

\[
\text{Annual Cost} = \frac{\text{Investment Cost}}{35} + \text{Yearly Operation & Maintenance Cost}
\]

Hour Cost of Transmission Line

\[
\text{Hour Cost} = \left( \frac{\text{Investment Cost}}{35} + \frac{\text{Yearly Operation & Maintenance Cost}}{8760} \right)
\]

Likewise, The cost of double circuit line in INPS Network is divided by two for the analysis purpose.

3. Result and Discussion

3.1 IEEE 14 Bus Case

The cost calculation for transmission line usage was done on the base case of IEEE 14 bus system for bilateral and multilateral transactions as shown in figure 1. The transaction 1 takes place between Bus 2 to Bus 5 for total load of 30 MW. The transaction 2 takes between Bus 2 to Bus 9 for total load of 40 MW. Table 1 presents the cost due to bilateral and multi transaction.

![Figure 1. IEEE 14 bus system.](image-url)
Table 1. Prices for Bilateral and Multi Transaction in IEEE 14 bus.

| Method | MW KM Method | MW Cost Method | MVA KM Method | MVA Cost Method |
|--------|--------------|----------------|---------------|-----------------|
| Pricing Variant | NET GROSS POSITIVE | NET GROSS POSITIVE | NET GROSS POSITIVE | NET GROSS POSITIVE |

Transaction 1

| Price ($/Hr) | 33.98 | 33.31 | 33.74 | 33.86 | 33.56 | 33.75 | 39.56 | 34.65 | 37.14 | 39.57 | 34.82 | 37.13 |
| Price ($/MWhr) | 1.13 | 1.11 | 1.12 | 1.13 | 1.12 | 1.13 | 1.32 | 1.16 | 1.24 | 1.12 | 1.16 | 1.24 |

Transaction 2

| Price ($/Hr) | 61.96 | 46.52 | 66.12 | 57.28 | 47.34 | 66.78 | 61.79 | 51.76 | 79.35 | 56.98 | 52.13 | 76.99 |
| Price ($/MWhr) | 1.55 | 1.16 | 1.65 | 1.43 | 1.18 | 1.66 | 1.54 | 1.29 | 1.98 | 1.42 | 1.3 | 1.92 |

Multilateral Transaction

| Price ($/Hr) | 44.5 | 74.65 | 145.17 | 44.21 | 70.84 | 165.58 | 71.78 | 70.71 | 113 | 73.02 | 74.65 | 79.16 |
| Price ($/MWhr) | 1.11 | 1.87 | 3.65 | 1.11 | 1.77 | 4.14 | 1.79 | 1.99 | 2.82 | 1.83 | 1.87 | 1.98 |

The prices from MVA KM and MVA Cost method are higher than MW KM and MW Cost method for both bilateral transaction and multi-lateral transaction. This indicates the more reactive power support in addition to the real power loading due to transactions in the system. Among the 3 pricing variants; Net, Gross and Positive, price is more in the Net approach in both MW and MVA methods for transaction 1. This is due to absence of reverse flows in the line used for the transaction. And since only one line is used for transaction between 2 buses, there is not much huge difference in variants. However, due to reverse flow in the line, the pricing is less in the Net approach in the both MW and MVA methods for the multilateral transaction.

3.2 INPS

Integrated Nepal Power system network consists of generators and loads connected to NEA network as shown in Figure 2. This network operates on the voltage level of 33 kV, 66kV and 132kV and the networks with voltage levels 220kV and 400 kV are under construction. During the analysis, only 66 KV and 132 kV are considered. There are 89 lines and 7 transformers in the system. Here, all the loads which are connected to the 33 kV are considered to be connected to the nearby respective loads centers instead. There are a total of 30 generators and 48 loads are considered in the INPS network during analysis. INPS is dominated by hydropower projects and most loads are residential loads. Dhalkebar with voltage level of 132 kV is considered as slack bus.
3.2.1 Bilateral Transaction in INPS

The bilateral transaction 1 takes place from Upper Marshyangdi to Simara, which amount to 50 MW in total, and bilateral transaction 2 takes place from Ilam to Mahendranagar, which amounts to 67.5 MW as shown in figure 3. The different pricing variant using MW KM, MW Cost, MVA KM and MVA Cost methods are presented in table 2. The three different variants; Net, Gross and Positive, are also calculated for MW and MVA methods respectively. Cost methods use average revenue requirement instead of line length. In both MW and MVA methods, the KM method is being costlier than the cost method. This is because of the change in the voltage level, i.e. for the same length of transmission line maintained at different voltage levels, the cost will vary. The negative wheeling charged using the MW Cost (NET) method in bilateral transaction 1 in INPS supports the use of MW Cost methods in the system. Furthermore, the positive MVA cost indicates reactive power loading during the transaction which is still not supported by the system. In both MW and MVA methods, KM method is costlier than the Cost methods. Moreover, in bilateral transaction 2, MVA KM and MVA Cost method price is higher which indicates that the current transaction is causing more reactive power loading in the lines.

Figure 2. Bilateral transaction for INPS.

3.2.2 Multi Transaction in INPS

The multi transaction takes place from generation plants Modi and Bhotekoshi, with the total generation 64.296 MW and the generated power is supplied to different loads at Damak, Shivapur and Kusum as shown in figure 4, where Damak Shivpur and Kusum are considered having equal loads of 21.432 MW and generations are 36 MW and 28.296 MW in Bhotekoshi and Modi respectively. From table 2, we can see that Net method does not ignore the negative changes in the transactions. MVA KM and MVA Cost methods prices are more than MW KM and MW Cost method respectively which indicates that this transaction is causing more reactive power loading. In bilateral transaction 1, there is huge difference
between KM and Cost method due to the change in voltage level of the lines. In transaction 2, prices are quite higher than transaction 1 due to the length of line and no change in the voltage level. The prices between multi and bilateral transactions are nearly equal to each other due to the use of multiple paths and length covered by multi transaction.

Figure 3. Multilateral transaction for INPS.
Table 2. Price for bilateral and multilateral transactions for INPS.

| Method          | MW KM Method | MW Cost Method | MVA KM Method | MVA Cost Method |
|-----------------|--------------|----------------|---------------|-----------------|
| Pricing Variant | NET, GROSS, POSITIVE | NET, GROSS, POSITIVE | NET, GROSS, POSITIVE | NET, GROSS, POSITIVE |
| Transaction 1   |              |                |               |                 |
| Price ($/Hr.)   | 146.21       | 123.73         | 79.71         | -4.17           |
| Price ($/MWh)   | 2.92         | 0.47           | 1.59          | -0.08           |
| Transaction 2   |              |                |               |                 |
| Price ($/Hr.)   | 696.52       | 741.58         | 773.31        | 697.26          |
| Price ($/MWh)   | 10.32        | 10.99          | 11.6          | 10.33           |
| Multilateral Transaction |         |                |               |                 |
| Price ($/Hr.)   | 619.14       | 638.2          | 758.41        | 635.38          |
| Price ($/MWh)   | 9.63         | 9.93           | 11.8          | 9.73            |

4. Conclusion
This paper uses the MVA KM and Cost methods for the computation of transmission line charges and comparison of the charges with other charges. During bilateral and multi-lateral transactions in IEEE 14 Bus and INPS Network, MVA KM and MVA Cost method price is higher which indicates that this transaction is causing more reactive power loading. Negative price indicates that they reduce the losses and support the system. MVA KM and Cost methods provide incentives for reactive power support to the system and provide incentives to do so. MVA methods encourage the efficient and reliable investment in the infrastructure needed to maintain the reliability of the transmission system. Transmission open access provides good incentives to the Genco’s as well as Disco’s and regulator have huge role in the open access system. In Nepal, unbundling process has started and newly endorsed regulator act has introduction of the open access of transmission line.

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