Transmission Connection and Charging Methodologies for Integration of Renewable Energy in Australia

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Abstract - **The Australian government is aiming to ensure that by 2020, 20% of Australia's electricity supply is generated from renewable sources. Consequently, this will drive large changes and have direct effects on the behavior and investment in Australia's market environment especially transmission use of system (TUoS) charges scheme. This paper is intended to explore the TUoS charges in the Australian national electricity market (NEM) to the development of renewable generation. There are three issues that are focused in this paper: 1) the transmission configurations for connecting the renewable generation to the existing grid; 2) the existing Australian NEM TUoS charges; and 3) the Australian energy market operator (AEMO) policy on the allocation of the cost of providing shared transmission services to different parties for new and existing terminal stations. The 59-bus system of the South East Australian power system is used for the case study in order to verify the concepts and determine the efficient and economical way to connect a new renewable generation to the existing grid.**

Keywords – Renewable energy target (RET) scheme, transmission use of system (TUoS) charges, transmission configurations, Australian energy market operator (AEMO) policy.

I. Introduction

The Australians are relying around 80% of coal for their electricity needs and this accounts for more than one third of Australia's current greenhouse gas emissions [1]. Therefore, in August 2009, the legislation for the expanded RET was passed by the Australian Parliament in order to provide 20 % of its energy generated from the renewable sources by 2020 [2-7]. Renewable energy sources such as wind, solar, geothermal heat and wave power will have a key role in moving Australia to the clean economy of the future. Currently, based on AEMO's planning [8] many new generation projects are seeking access to the Victorian electricity declared shared network. AEMO has received 5,000 MW of connection applications and enquiries to connect to the Victorian transmission system. Of these, about 3,600 MW are expected to be connected to the 500 kV lines between Moorabool and Heywood and the rest to the 220 kV lines out of Ballarat. These new generation development proposals are aiming to capitalize on Victoria's substantial wind and gas resources while utilizing the existing electricity infrastructure along the south-western coast of Victoria and in the Ballarat region.

The expanded RET has significant impact on the Australian NEM system. As indicated, the expanded RET will stimulate investments in new renewable generation capacity. This new generation is likely to be predominately wind-powered, clustered in specific geographical areas and often remote from the grid. The results for networks will be an increase in connection applications for remote renewable and requirements for investment in the shared network [2]. In Australia, the regulatory investment test for transmission (RIT-T) is applied to assess the merits of different generation connection options [9-11]. It accompanies AEMO's cost allocation methodology, which explains how AEMO will allocate shared network costs between generation connection applicants (applicants) connecting to the same terminal station [10].

II. Transmission Configurations

Three types of transmission configurations commonly used by AEMO have been introduced in order to connect the generator of a remote generation cluster to the existing grid that are "spaghetti network", scale efficient network extension (SENE)-simple approach and SENE-hub approach [11].

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A. *"Spaghetti network"*

In Australia, the current regulatory regime does not provide any incentive to the transmission network service providers (TNSPs) to take the advantage of the potential scale efficiency of HV/UHV transmission, or an efficient configuration of the network to build a network in anticipation of future connections [11]. A typical RIT-T application may or may not support such efficient transmission development. Generators are in such cases left to negotiate a connection arrangement with the TNSPs that would typically see a "piecemeal" or "spaghetti network" development of the transmission system, potentially involving multiple lower voltage lines and duplication of connection assets.

B. *Scale Efficient Network Extension (SENE)-simple approach*

The Australian Energy Market Commission (AEMC) have recommended the SENEs in order to help promote the efficient connection of clusters of new generation to the electricity networks as a new generation connects over a period of time [12]. These types of connections are mostly due to the characteristics of fuel resources for renewable energy generation that are generally remote from the shared networks. The Ministerial Council on Energy (MCE) endorsed the AEMC's recommendation and in February 2010, requested the AEMC to progress on the consideration of the associated SENE rule change proposal, with regard to the MCE's response and suggested amendments. The AEMC formally commenced its consideration of the rule change request and first round of consultation in April 2010.

C. *Scale Efficient Network Extension (SENE)-hub approach*

A third available option is to connect generators into hubs that are created at appropriate locations within an assigned region, like Regional Victoria or the South-West Corridor [8]. AEMO has proposed new connection hubs purposely to solve the technical issues associated with the connection of new generators to the electricity declared shared network. Hubs provide the following benefits to the generators and Transmission Network Service Providers (TNSPs) [8]:

- they maintain the transmission system's reliability and ensure flow path continuity;
- they reduce the transmission constraints during construction, and during planned and unplanned outages;
- they allow for easier network expansion when accommodating future connections and system augmentations;
- they enable generation proponents to incorporate AEMO's planned connection arrangements and readily available infrastructure in their project plans; and
- they save costs to connecting parties by sharing connection assets.

III. NEM Transmission Pricing

There are two types of transmission pricing methods that have been adopted by Australian NEM which are the cost reflective network pricing (CRNP) and modified cost reflective network pricing (MCRNP) methods. The TNSPs that use CRNP method are Transend Networks, TransGrid and Vencorp whereas ElectraNet uses MCRNP method for its transmission charging.

The CRNP methodology generally involves the following steps [13]:

1. Determining the annual costs of the individual transmission network assets in the optimised transmission network;
2. Determining the proportion of each individual network element utilised in providing a transmission service to each point in the network for specified operating conditions.
3. Determining the maximum flow imposed on each transmission element by load at each connection point over a set of operating conditions.
4. Allocating the costs attributed to the individual transmission elements to loads based on the proportionate use of the elements.
5. Determining the total cost (lump sum) allocated to each point by adding the share of the costs of each individual network attributed to each point in the network.

Meanwhile, MCRNP methodology is an allocation process that involves replacing step 1 of the CRNP methodology referred to in clause S6A.3.2(1) with the following three steps [14]:

1. Allocating the Annual Service Revenue Requirement (ASRR) allocated to prescribed use of system services to each transmission system asset used to provide prescribed TUoS services based on the ratio of the optimised replacement cost of the that asset to the optimised replacement cost of all transmission system assets used to provide prescribed TUoS services. The amount allocated to each asset is the asset's gross network asset cost.
2. Adjusting individual gross network asset costs: the individual gross network asset costs determined in MCRNP point (1) methodology must be multiplied by a factor (between 0 and 1) that depends on the utilisation of each asset. The resulting amount for each asset is the locational network asset cost while the remainder is the non-locational network asset cost.
3. Determining the non-locational component: the sum of the non-locational network asset cost represents the pre-adjusted non-locational component of the ASRR for prescribed TUoS services.

IV. THE AEMO'S COST ALLOCATION POLICY FOR NEW AND EXISTING TERMINAL STATIONS

AEMO has outlined the cost allocation policy for new and existing terminal stations. In determining this policy, AEMO has been guided by the *national electricity objective*, which seeks to promote the efficient operation and investment in the market for the long-term benefit of consumers, taking into account of price, reliability, security and safety [9].

A. Various Types of Application for New Connections

This policy covers three different situations where the costs of establishing and augmenting a terminal station are allocated. These situations are [9]:

1. *An initial connection:* New terminal stations are designed in accordance with AEMO's guidelines for establishing terminal stations, with the initial connections being in accordance with AEMO's guidelines for shared transmission connections. The location and design of a terminal station may be proposed by an applicant or specified by AEMO. The cost of an initial connection situated at the applicant's preferred location will be borne entirely by the applicant. If AEMO requires the connection to be made at a location other than the applicant's preferred location, the applicant will not be required to pay more than what it would have paid if it had connected at the applicant's preferred location. This requires that the additional costs associated with establishing the terminal station at AEMO's preferred location satisfies a RIT-T assessment and can be classified as prescribed services.

2. An incremental connection: An incremental connection occurs where one or more applicants intend to connect generating plant at an existing terminal station without triggering the need of major expansion. In other words, the initial connection arrangement for the terminal station is expandable and can accommodate additional connections.

3. An expansion connection: An expansion connection occurs where subsequent generation connections can only be accommodated if there is a major expansion of the terminal station involving a substantial investment. Examples of major expansion include:

- Conversion from a tee connection to a double-switching or breaker-and-a-half switching of connecting transmission lines;
- Connection of terminal station to the network via an additional transmission line.

B. Applying the RIT-T to multi-connection terminal stations

In [10], the RIT-T can be used to find out which location and design of terminal station provides the greatest net benefit to the NEM. The RIT-T guidelines, published by the Australian energy regulatory (AER), outline the example when a TNSP may find it efficient to configure connection assets in such a way as to allow them to easily augment in the future should additional demand for connections arise, so this application of the RIT-T is already accepted. However, the RIT-T cannot be used to determine what proportion of generation connection costs should be negotiated versus prescribed. The RIT-T is indifferent to who is paying costs or providing benefits (that is, the TNSP or Applicant) – all costs are assumed to be passed through to the end-user.

The RIT-T application guidelines describe the following steps involved in applying the RIT-T [10]:

Step 1: Identify a need for the investment (known as the identified need);
Step 2: Identify the base case and a set of credible options to address the identified need;
Step 3: Identify a set of reasonable scenarios that are appropriate to the credible options under consideration;
Step 4: Quantify the expected costs of each credible option;
Step 5: Quantify the expected market benefits of each credible option – calculated over a probability weighted range of reasonable scenarios.

However, in this paper step 4 is further discussed as follows as it is related to the TUoS charges for new entrance of generation.

The costs in a RIT-T are defined as the present value of the direct costs or incremental costs of a credible option. The incremental costs include [8, 10]:

- The costs incurred in constructing or providing the option;
- The operating and maintenance costs in respect of operating life of the credible option;
- The costs of complying with any mandatory requirements in relevant laws, regulations and administrative requirements.

It is necessary to define "the option" before calculating the incremental costs. The identified need under RIT-T is to connect multiple generating plants in an economically efficient way, and to do this requires:

- Correct sizing of connection and shared network assets at the terminal station;
- Correct location of the terminal station.

Given that the identified need of RIT-T is not a need to supply the additional generation capacity; the RIT-T should not be used to justify any costs an applicant would pay to connect without the terminal station. The option and the incremental costs therefore consists of only the difference between the works required to connect the first applicant at its preferred location and the works required to establish the terminal station. This difference in costs is allocated to prescribed transmission services and subtracted from the costs of establishing the terminal station. The remaining non-prescribed costs of establishing the terminal station are shared between future connecting applicants under the standard cost allocation methodology. Summary of determining the prescribed transmission services or additional TUoS charges is shown in Figure 1. These additional TUoS charges are to be fully paid by the load.

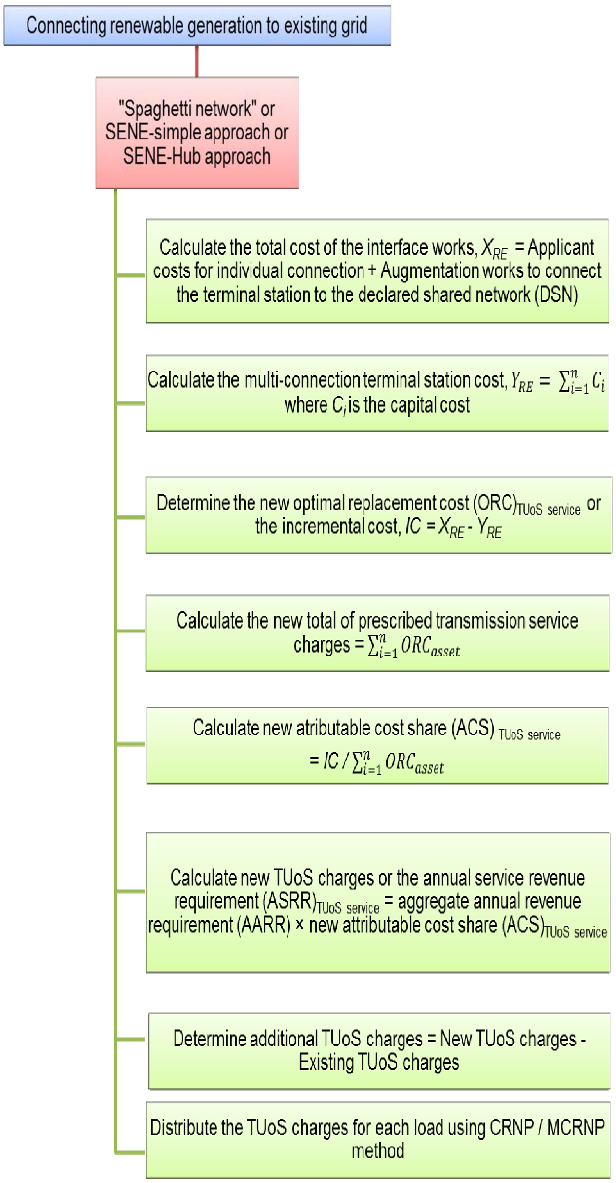

Figure 1. Summary of determining additional TUoS charges for new entry of generation.

V. CASE STUDY

A modified version of the 59-bus system of the South East Australian power system as shown in Figure 2 has been simulated to verify the concept. This case study is based on the DC power flow where losses are neglected. The generators serve a total system demand of 22300 MW and detail parameters can be found in [15] with 800 MW of wind power as new generation entry. Table I presents the generation data for the base and modified system after addition of 800MW wind generation. For calculating the TUoS charges, the assumed capital costs for applicant shown in Figure 3 are used. Let the transmission revenue is $20,500,700 and assuming the Aggregate Annual Revenue Requirement (AARR) is $23,296,250 [13].

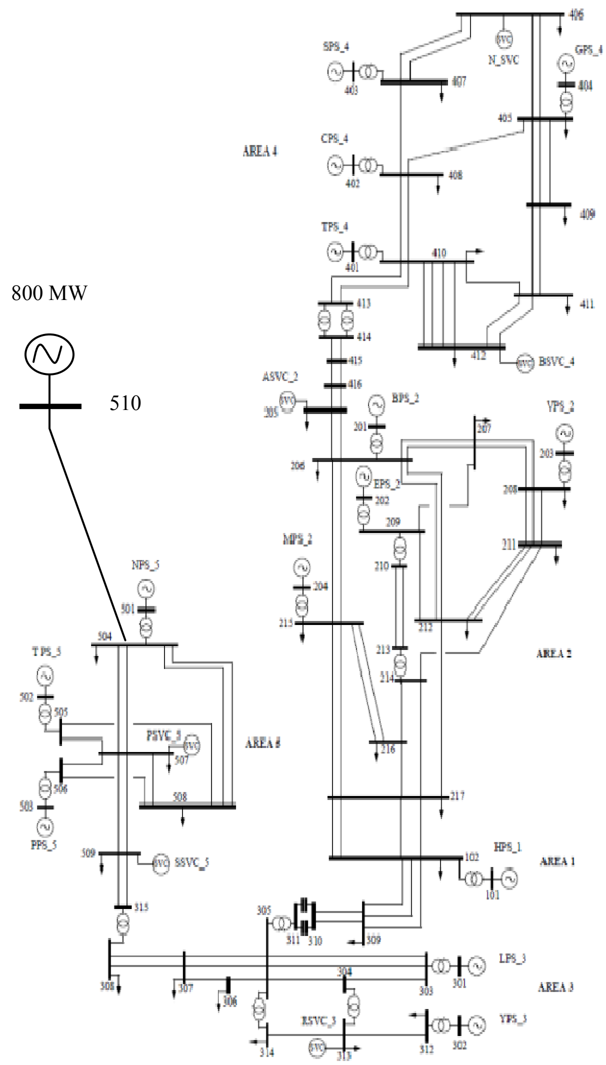

Figure 2. The modified 59-bus system of the South East Australian Grid.

TABLE I. GENERATION DATA FOR BASE SYSTEM

Generator	Technology	Capacity (MW)	% Generation
G101	Oil	317.2	1.4
G201	Coal	3600 [3200]*	16.1 [14.3]*
G202	Coal	2500	11.2
G203	Coal	1500 [1400]*	6.7 [6.3]*
G204	Coal	2770.2	12.4
G301	Coal	4200	18.8
G302	Hydro	939.9	4.2
G401	Gas	1400 [1200]*	6.3 [5.4]*
G402	Coal	837	3.8
G403	Gas	1400 [1300]*	6.3 [5.8]*
G404	Coal	1549.8	6.9
G501	Gas	600	2.7
G502	Others	576.9	2.6
G503	Coal	109	0.5
G510	Wind	[800]*	[3.6]*
Total		22300	100

*After addition of 800 MW of wind generation

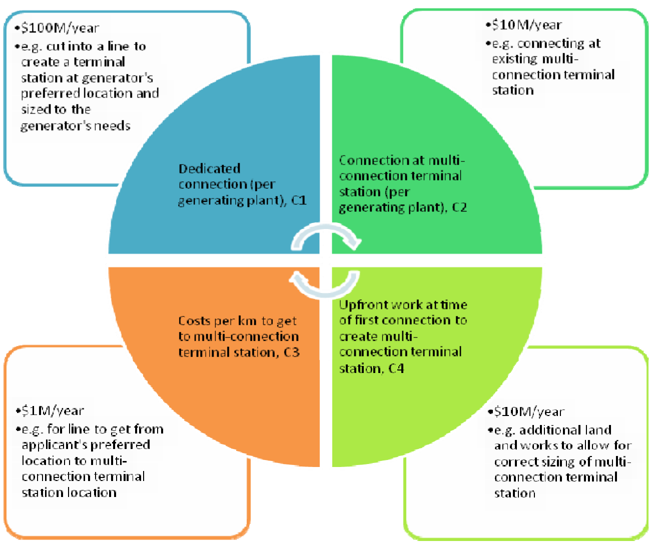

Figure 3. The assumed capital costs for an applicant.

The spaghetti and SENE-simple topology is simulated for 100 km transmission length. For the SENE-hub, the length for the transmission line is reduced to 60 km. The transmission cost is considered $1M per km.

A. Results and Analysis

Table II shows the comparison of the transmission service charges for the base case and different network connections by using CRNP and MCRNP methods. It clearly shows that with a new 100 km of transmission line systems for the SENE-simple approach has resulted the highest total charges compare to the SENE-hub approach which augmented 60 km of the new network system. In this case study, the "spaghetti network" is assumed to be located at the applicant's preferred location. Therefore, results from Table II show that the total charge for the "spaghetti network" is similar to the base case. Full cost is covered by the generator.

TABLE II. COMPARISON OF THE TRANSMISSION SERVICE CHARGES FOR THE BASE CASE AND DIFFERENT NETWORK CONNECTIONS BY USING CRNP AND MCRNP METHOD

Load	Transmission service charges, $			
	Base case	Spaghetti network	SENE-simple	SENE-hub
L102	413,691.26	413,691.26	431,884.28	415,764.52
L205	358,532.42	358,532.42	374,299.70	360,329.26
L206	119,510.80	119,510.80	124,766.56	120,109.76
L207	1,728,310.14	1,728,310.14	1,804,316.52	1,736,971.80
L208	193,055.92	193,055.92	201,546.00	194,023.44
L211	1,562,833.62	1,562,833.62	1,631,562.80	1,570,665.98
L210	1,526,061.08	1,526,061.08	1,593,173.08	1,533,709.14
L215	441,270.68	441,270.68	460,676.56	443,482.16
L216	1,691,537.58	1,691,537.58	1,765,926.80	1,700,014.94
L217	1,158,335.52	1,158,335.52	1,209,275.96	1,164,140.66
L306	1,130,756.10	1,130,756.10	1,180,483.68	1,136,423.04
L307	597,554.04	597,554.04	623,832.84	600,548.76
L308	602,150.60	602,150.60	628,631.56	605,168.36
L309	179,266.22	179,266.22	187,149.86	180,164.61
L312	105,721.10	105,721.10	110,370.41	106,250.94
L313	2,210,949.94	2,210,949.94	2,308,181.50	2,222,030.40
L314	229,828.48	229,828.48	239,935.70	230,980.30
L405	910,120.76	910,120.76	950,145.40	914,681.96
L406	680,292.28	680,292.28	710,209.70	683,701.66
L408	137,897.08	137,897.08	143,961.42	138,588.18
L409	239,021.62	239,021.62	249,533.14	240,219.50
L410	487,236.36	487,236.36	508,663.70	489,678.22
L411	528,605.50	528,605.50	551,852.12	531,254.68
L412	1,153,738.94	1,153,738.94	1,204,477.24	1,159,521.06
L504	275,794.18	275,794.18	287,922.84	277,176.34
L507	919,313.90	919,313.90	959,742.82	923,921.16
L508	735,451.12	735,451.12	767,794.26	739,136.94
L509	183,862.78	183,862.78	191,948.56	184,784.24
Total	**20,500,700.00**	**20,500,700.00**	**21,402,265.00**	**20,603,442.00**

In Figure 4, it can be clearly seen that the multi-connection terminal cost of wind generation which is borne by the applicant for the "spaghetti network" is the highest because the applicant has to bear the 100km line cost to be built between the generating plant and the multi-connection terminal station compare to the SENE-hub which is only 40km additional line. For SENE-simple, there is no additional line is needed therefore the total capital cost is less as the generator have to cover only the cost of development of the new multi-connection terminal station.

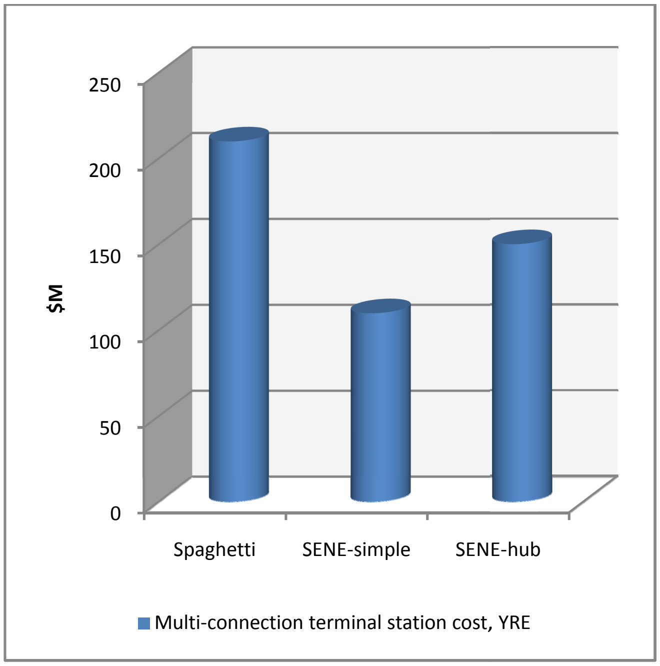

Figure 4. The multi-connection terminal station cost of wind generation for different types of connections.

VI. CONCLUSION

This paper has identified the transmission service charges allocated for "spaghetti network", SENE-simple and SENE-hub. The "spaghetti network" is not an efficient and economic option for grid connection, especially for remote locations in which full cost is borne entirely by the generators. The SENE-simple approach is introduced to overcome the "spaghetti network" drawbacks and to achieve 'economies of scale' through efficient use of the network but unfortunately, it contributes high TUoS charges and generation capital cost. Therefore, it can be concluded that the SENE-hub approach is the best connection to be applied as the total charges for the generation capital cost and TUoS services are well balanced compare to the other connections. This approach provides an efficient and economical way to connect a new generation especially wind power as majority of them are located far from the existing grid.

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