

Benefit-based expansion cost allocation for large scale remote renewable power integration into the Australian grid



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HIGHLIGHTS

- Shapley Value approach offers a fair and equitable cost allocation.
- A case study of the Australian Queensland network is presented.
- Cost allocation is contentious for remote renewable power transmission.
- Regulatory policies and planning frameworks need to be updated.

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ABSTRACT

Climate change policies in different jurisdictions enhance the integration of large scale remote renewable power generation into the grid, where the remoteness of the location-constrained generation zone and subsequent high transmission investment appear as a potential barrier. Consequently the justification of investment and equitable cost allocation becomes contentious. This research firstly presents a state-of-the-art review of policy changes in different jurisdictions in this aspect. Then transmission connection and usage cost allocation are presented to address these challenges accordingly, highlighting the implementation of semi-shallow connection cost allocation policy. Afterwards, the benefit-based allocation of network usage cost is reimbursed through Shapley Value approach. Finally, the investigation of the net market benefit and cost allocation are presented by simulating four large scale remote renewable transmission projects to be connected to the Australian Queensland network. This study aims to enhance regulatory policies and associated planning frameworks to be more efficient and justifiable for renewable power integration paradigm.

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1. Introduction

Climate change policies along with emission pricing strategies worldwide influence power system planning approaches to ascertain a low emission power sector. This trend enhances the integration of large scale renewable power sources into the grid. As potential large scale renewable energy sites are generally located far away from the consumptions centres, transmission infrastructure development is required to reach those location-constrained remote zones. Thereby integration of large scale renewable energy to the grid goes hand in hand with a significant investment in extensive transmission infrastructure [1,2]. Accordingly the share of transmission cost for network users becomes large compared to a conventional generator connection to the grid. This problem

turns out to be noticeable in large countries where a transmission line expands 1000 km to reach a remote generation zone [3–5].

For instance, the Renewable Energy Target (RET) in Australia is targeted to integrate 6000–8000 MW renewable power to the grid by 2020 [6]. To be coherent to the RET, 4000 MW geothermal power is expected to realize step-by-step by 2030 from ‘Cooper Basin’ resources, which is located in the range of 1000 km from the existing Queensland grid [7]. Also, the proposed ‘Kennedy Wind Farm’ (700 MW) is located around 300 km away from the existing grid of North Queensland [8]. The ‘Copper String’ project is expected to connect 400 MW renewable power from the North-West Queensland to the grid through a 700 km long transmission line [9]. Besides 1800 MW hydro power is expected to import to the Australian National Electricity Market (NEM) via North Queensland from Papua New Guinea (PNG), through a 250 km subsea interconnection and 200 km transmission infrastructure.

All of the abovementioned large scale remote renewable projects have to go through the traditional Australian Regulatory

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Investment Test for Transmission (RIT-T), which is primarily designed for explicit cost benefit assessment of market benefit of transmission for conventional generation. While the RIT-T has a number of attractive features, it also has some shortcomings when it comes to large scale renewable power integration into the grid from a remote location [10]. Under the Australian NEM regime, location-constrained renewable generators have to undergo through the same transmission cost allocation policy which is basically designed for conventional generation plants and generally overlooks the remoteness of renewable sites. It is evident that the existing RIT-T framework does not provide adequate incentive to get some of the efficient transmission investments off the ground, which is eventually shutting off significant green energy opportunities for ever [10]. Keeping this in mind, the current study evaluates the connection cost (investment) and network cost (O&M) allocation policies practiced in different jurisdictions worldwide in the context of large scale remote renewable power integration into the grid.

The rest of the paper is organized as follows. Section 2 presents an overview of transmission cost allocation methodologies in the context of large scale renewable energy, followed by Australian transmission cost allocation practices in Section 3. Then the proposed approach of transmission cost allocation in the context of large scale renewable energy is presented in Section 4. Further, Section 5 describes the Australian case studies of large scale remote renewable power integration into the NEM grid. Subsequently, results and analysis are presented in Section 6, followed by conclusions in Section 7.

2. Transmission cost allocation in the context of large scale renewable energy – an overview

In a broad sense, there are two parts of the transmission expansion costs needed to be considered – the connection cost and the network cost. These two types of costs are described below in the context of large scale renewable energy integration into the network, followed by the changing trend of cost allocation in different jurisdictions to cope with the renewable energy scale-up.

2.1. Connection costs

Transmission connection cost allocation approaches are generally classified as super-shallow, semi-shallow, shallow and deep connection pricing. Market operators' policies in different jurisdictions allow renewable generators to pay connection costs at different extents. Fig. 1 shows the cost allocation approaches of grid integration, which are adopted from the European RES-E (Renewable Energy Resources for Electricity) policy [11]. Super-shallow charge does not include the cost related to the grid integration.

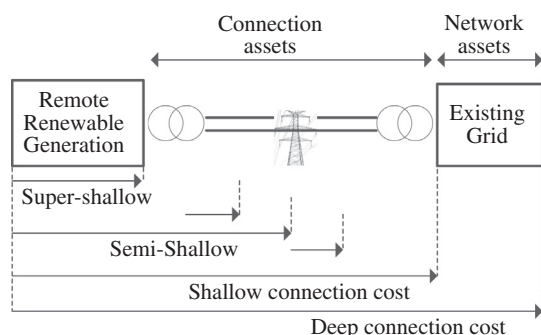


Fig. 1. Connection costs allocation approaches for remote renewable generation connection [11].

Renewable generators are responsible for only the generation development in such a cost allocation policy. The costs of network integration and reinforcement are borne by Transmission Network Service Providers (TNSP) and consecutively shared by network users. On the other hand, some jurisdictions adopt a provision to divide the grid-integration cost among generators and consumers. This type of partial connection cost allocation for generators is known as semi-shallow policy. The proportion of connection cost-share for generation depends on its negotiation with the TNSP.

Further, shallow connection charge imposes the cost of connecting plants to the grid fully on renewable generators. For a remotely located renewable generator, this cost is significant, even can be in the range of few hundred million to few billion dollars in some cases.

Furthermore, the deep charging policy imposes grid connection and reinforcement costs on generators. So generators have to pay the network integration as well as shared network usage cost according to the deep connection charge arrangement. A high transmission connection cost in a deep connection policy may discourage renewable integration into the grid. So, operators cost allocation policies have potential impacts on renewable energy integration and largely influences the viability of renewable investment.

2.1.1. Changing trend of connection cost allocation in the context of remote renewable energy

Many regulatory regimes are updating their connection cost allocation policies for remote renewable power integration to the grid [12]. Table 1 presents the changing trend of transmission connection cost allocation policies in different jurisdictions to enhance large scale remote renewable generation into the grid. The GB practices super-shallow cost allocation policy for renewable generators, in case of its shallow approach for conventional generation. Denmark and Germany traditionally practice shallow connection cost policy. Currently these jurisdictions offer super-shallow policy for offshore wind farms. Spain changes its deep connection policy to shallow for renewable integration. Even in some instances semi-shallow approach is adopted in Spain. Also, semi-shallow cost allocation policy is reported in Texas, Panama and the Philippines' jurisdictions. There was no specified policy for transmission connection of conventional generators in Europe. So, different European countries practiced different transmission policies. Recently, the European Union (EU) recommends the semi-shallow charging policy to be "preferable and favourable" for renewable energy integration [13].

2.2. Network costs

While connection cost allocates the cost of network integration, the network cost allocation recoups the operation and maintenance costs of the shared network. Some of the jurisdictions, e.g. the Australian NEM, refer network cost as the Transmission Use of System (TUOS) charges [14]. Varieties of options to distribute network costs among network users are shown in Fig. 2. The network cost is recovered through either the postage stamp or usage based method. The postage stamp method imposes an average charge based on the amount of energy transmitted through the network, regardless of the location of generators/consumers. Postage stamp charge is allocated based on either the energy consumption or peak demand. In the usage based cost allocation, charges are imposed based on 'the extent of use' of the physical network. Usage based method recovers the network cost either through flow-based or distance based charging. Different network cost allocation policies have different impacts on a large scale renewable integration into the grid.

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