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A 'Regional Energy Hub' for achieving a low-carbon energy transition

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ABSTRACT

The transition to a low-carbon energy economy will remain a cornerstone of national energy policies of countries committed to the climate change accord for decades to come. We think that transmission investment is one key policy instrument amongst other to help with this transition. We propose an enhanced role for investing in transmission capacity for inter-regional trade to allow effective fuel switching among countries through a physically connected market. We develop a conceptual framework of "Regional Energy Hubs" and propose a cost minimization model in support of a transmission investment strategy that integrates: (i) a key geopolitical parameter for countries that are geographically close in a region but under different political jurisdictions, judged as stable and receptive to firm trading arrangements, (ii) an economic parameter related to the fuel mix where the differences in a country's supply and demand characteristics are significant enough for allow mutual benefits to be realized through cost reduction, (iii) an environmental parameter linked to a country's carbon intensity that could benefit from the resources of a neighboring jurisdiction with lower intensities, and (iv) a financial parameter for each country within a region capable of attracting investment capital. A connected 'Regional Energy Hub' offers large economic and environmental benefit for transition to a low-carbon energy economy.

1. Introduction

Prior to liberalization of electricity markets, transmission investment decisions often resulted in overcapacity of the built system (Joskow, 2006). Transmission investment decisions were primarily based on matching the demand (load) with generation requirements to maintain the system reliability (Joskow et al., 2008). Currently, decision making process for transmission investments is still heavily influenced by the monopolistic nature of the transmission system infrastructure. The dichotomy arises from a deregulation effort that was primarily confined to the generation and distribution of the regulated utility assets, but transmission system ownership remained as a regulated monopoly and this in turn caused transmission investments to lag behind the generation investment (i.e., centralized transmission planning versus decentralized generation investments) (Pfeifenberger, 2012). Although several options ranging from pure merchant to fully regulated options were developed to incentivize investments, the transmission system could not keep up with the demand and new emerging generation capacity with increasing share of renewable generation with variable and intermittent output on the system. Transmission investments initially flourished in the electricity markets in several countries (e.g., United Kingdom –UK, United States –US, Norway, Sweden) led by a few transmission system operators (TSOs) (e.g., National Grid, Pennsylvania-New Jersey-Maryland –PJM, Stattnet, Swenska kraftnat, respectively), but further developments of the wholesale markets have not been robust with the consequences that congestion is notable, the investment and integration pathways are unclear and regional capacity planning issues among the markets and the regions are emerging (Ramachandra, 2009).

In this paper, we propose a new perspective on regional transmission investments in the evolving organized electricity markets and energy policy requirements. Besides providing engineering reliability and facilitating economic trade as the two major objectives of transmission investments (Conejo et al., 2016), we propose the concept of a 'Regional Energy Hub' (REH) that integrates key geopolitical, economic, environmental and financial factors to foster investment decisions for transmission adequacy. A REH enabled through requisite transmission capacity becomes an investment option for regional optimization of diverse supply resource needs to come into play from similar concepts introduced earlier (FERC, 2011; OFGEM, 2010; EC). We argue that transmission has a positive and increasing role in the evolving convergence of climate change policies as they relate to connected markets, integration of large amounts of renewable generation and removal of congestion bottlenecks in the system. The goal is to optimize

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underutilized generation capacities over a wide geographic area through additional transmission interconnectors and to assess the benefits from a regional perspective that would support a low-carbon energy economy across several independent jurisdictions and countries (Ochoa and van Ackere, 2015; Aguado et al., 2004; EPRI, 2014).

We describe a novel framework for enabling a robust basis for transmission investments that take into account most considerations/opportunities for optimization on a regional basis, but excluding stochasticity, robustness from optimization perspective and risk-neutrality issues. Therefore, the objective of this paper is to:

i. develop a definition of the concept of REH to improve and verify transmission investments against a set of considerations that include the geopolitical, economic, environmental and financial perspectives (i.e., the REH factors),
ii. develop a framework for identifying the REH and the key factors so that the benefits for the region are better ascertained and measured,
iii. develop a generic mathematical model based on (i) and (ii) above, and to apply this model to the evaluation of a case study for the Romania-Turkey transmission investment,
iv. quantify benefits for the defined region according to the REH factors.

We build upon the existing body of knowledge on transmission investment approaches to help clarify the convergence of two high-level policy goals: energy policy as an integral part of climate change mitigation and adaptation strategies. The REH approach has the potential to provide key insights on how the transmission investments and effective pathways for enhanced electricity trade can pave the way for a broader de-carbonization strategy at a lower cost to all consumers.

More importantly, we think that REH framework could serve as a platform to (i) identify the need for further investigation into adaptation strategies such as transmission planning, generation expansion (i.e. renewables), demand side response, or storage; however, the purpose of this study is not to investigate these adaptation strategies individually, which is already studied extensively, but (ii) to capture and consider them from a regional perspective so that transition to low-carbon energy economy is effective.

The paper is organized as follows: Section 2 reviews the literature on transmission investment in electricity markets, as well as the issues, challenges and barriers of the current state of the art. Section 3 defines the research problem and the objective of this study, whereas Section 4 frames the methodology in approaching the research problem. Section 5 concludes with a case study for Turkey-Romania interconnector investment decision where REH is applied and benefits are quantified.

2. Background

As the market economy has evolved around the world, many countries have opted for liberalization of their electricity market starting as early as 1980s in Chile and the UK (Pollitt, 2004). By 1990s, many countries have had functioning liberal electricity markets (Stridbaek et al., 2006).

Prior to the liberalization of the electricity markets, states regulated the electricity value chain. It had a monopolistic model from generation to transmission such that they were state (publicly) owned generators, transmission and distribution companies, and no functioning wholesale or retail market. In this context, the transmission investment planning and decision-making were centralized and rather simple. Central planners of the state projected the transmission investments along with the generation expansion. The transmission has acted as the highway of delivering electrical energy to the generation to the load. Traditionally, it was designed to meet the expected demand in the future within a region or a country while taking into account reliability issues. Main rationales for transmission investment were: technical reliability and economic efficiency, which often resulted in an overcapacity or lumpiness (Joskow et al., 2008). During the liberalization phase, the initial overcapacity and growth of privately-owned power generators helped develop the wholesale markets by trading across many counterparties (Brunekreeft et al., 2005; Pfeifenberger, 2012). This resulted in transmission capacity to be used efficiently to improve system reliability, to create liquidity, and to reduce market power.

In time, transmission investment has suffered from long lead times due to monopolistic nature of the infrastructure (Joskow and Tirole, 2005) and in many of the countries and regions, transmission capacity has not kept up with the demand growth and generation expansion. Another factor affecting the transmission investment has been the bottom-up nature of the planning process, although extensively studied (Kazempour, 2013), it has not helped with the real transmission investment problem that is faced today. What has been missed in those models was transmission planning conducted by utilities that do not consider regional integration (Lévêque, 2007). Therefore, transmission investment, although initially flourished the wholesale markets, now prevents further developments due to congestion issues, particularly between the markets and/or the regions. This has caused congested line failures and also cascading errors in voltage and frequency stability. To overcome these transmission investment hurdle, many solutions have been developed ranging from fully merchant (market) based forms to fully regulated forms (e.g., financial transmission rights –FTRs and physical transmission rights –PTRs), but none were efficient to keep up with the demand and new generation capacity (Pollitt, 2012; Rosellón et al., 2011; Wu et al., 2006). The major difficulty has always been to assess the cost/benefit measures of the investment process (Joskow et al., 2008; Chang et al., 2013). Although economic benefits and technical reliability parameters provided the main inputs for transmission planning prior to the liberalization period, many projects now have to account for the wide range of economic and/or public-policy benefits in the deregulated markets for increased competition and liquidity (Chang et al., 2013).

Along with the transmission investment challenges, today's electricity markets must address a number of key issues as follows:

i. Lowering air pollutant emissions (IPCC, 2014), although a recent study by Howarth (2014) argues that both shale gas and conventional natural gas have a larger GHG (Green House Gas) emissions than do coal or oil;
ii. deciding on investment and/or replacement in generation (i.e., coal power and/or nuclear power plants);
iii. deciding on investment and replacement in transmission system (Hogan, 1999);
iv. integrating renewable sources (Schumacher et al., 2009) and storage into their system (Pollitt, 2016);
v. increasing energy trading among countries by connecting markets (Newbery et al., 2016);
vi. increasing reliability upgrades and generation interconnection;
vii. overcoming congestion problems (Hogan, 1999);
viii. overcoming market design issues preventing coordination among countries (Imran and Kockar, 2014); and
ix. overcoming market design differences (Kassakian et al., 2011).

In the light of the aforementioned transmission investment challenges as well as the evolving electricity market and climate change requirements, there is a need for a radically new approach to reconsider the transmission investment from different perspectives that support the transition to a low-carbon energy economy. We think that all these common challenges, as well as the climate change policy constraints, can be overcome by a novel (top-down) approach to transmission investment strategy. In this context, REH is a transmission investment model to provide key insights to the policy makers in achieving a low carbon energy transition regionally.