INSTITUTO DE INVESTIGACIÓN TECNOLÓGICA

FINAL REPORT

STEXEM

Task 4: Dissemination and Exploitation

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1. Dissemination and Exploitation

This task consists of those activities aiming at communicating, integrating, sharing knowledge, and disseminating STEXEM achievements to the target audience of the project such as GENCOs, TSOs, RE technology manufacturers, and, more generally, chambers of commerce and policymakers with regulatory impact. Dissemination activities aim at giving more visibility to the project's achievements in nationally and internationally, thereby helping to deepen knowledge on the low-carbon energy transition to the targeted audience.

As a consequence, we have set-up a web page with the activities of the STEXEM Project. On this web page, a brief description of the researchers and the working team is presented; additionally all STEXEM project-related conferences, publications and research stays are described. Relevant documents are made available on this webpage. The page is available in both Spanish (ES) and English (EN) to increase dissemination. The STEXEM web page can be accessed through the following link: https://stexem.iit.comillas.edu/es/

1.1 Participation in events of awareness-raising activities (T.4.1)

The members of the research group have participated in different conferences and events which have taken place around Europe (The Netherlands, Spain, Ireland) and US (Texas). Below we list the aforementioned conferences and, in brackets, we show the related task.

1.1.1 Enhanced representative days and system states modeling for energy storage investment (T1.1)

D.A. Tejada, S. Wogrin, E. Centeno, Enhanced representative days and system states modeling for energy storage investment, INFORMS Annual Meeting – INFORMS 2017. Houston, Unites States, 22-25 October 2017.

Abstract: In this work, we analyze the impact of different options to represent the operation decisions in the study of energy storage (ES) investment for long-term planning models. We compare the representative days and the system-states approaches for the representation of these operation decisions. We proposed enhanced versions of these approaches to improve the ES investment approximation. A Spanish case study is evaluated and the results are used to identify the potential profits that energy storage investment can obtain.

1.1.2 Proactive Bi-level GEPTEP with storage considerations (T.2.2)

I.C. Gonzalez-Romero, S. Wogrin, T. Gomez. Proactive Bi-level GEPTEP with storage considerations. 24th Young Energy Economist and Engineers Seminar (YEEES). April 12 and 13 2018 Delft, The Netherlands.

Abstract: This paper proposes a bi-level formulation for the generation and transmission coordination problem (GEPTEP). We consider a proactive framework in which a centralized TRANSCO represents the upper level while the decentralized GENCOs, that trade in the market, represent the lower level. As a novel feature, a representative period framework is employed, which allows us to consider operation of in both short and long-term storage technologies. A case study is presented to compare the results between a one-level cost minimization framework and a bi-level proactive framework.

1.1.3 Situational awareness and control of distribution systems and interaction with transmission systems (T1)

Tomás Gomez. Situational awareness and control of distribution systems and interaction with transmission systems. XX Power System Computation Conference (PSCC), Dublin, Ireland. 11 -15 June 2018. (Presentation)

With the Kyoto and Paris climate agreements countries worldwide agreed to reduce their greenhouse gas emissions. As a consequence, renewable energy sources are introduced and power systems are facing new challenges. This paper gives a survey of the challenges occurring in distribution systems worldwide with a focus on their automation and control including situational awareness, monitoring and supervision. Through the first part, the paper discusses the changing framework for distribution systems, the current industry practices, future enhancements and available options. An overview of sensors, actuators, communication systems and control center functions required for observability and controllability is given. Further, notable research activities and pilot projects all around the world are introduced. Microgrids and so-called Smart Grids are particularly discussed and differences and similarities of the projects are indicated. Progressing beyond research towards industrial practice is only possible if driven by the markets or government legislation. Thus, an overview on market issues for future distribution grids is given and new market mechanisms and government regulations are critically evaluated. Changes in distribution systems will also impact their interaction with generators and transmission systems. The new responsibilities of distribution system operators and the need for advanced data exchange between distribution and transmission operators are discussed. Finally, an outlook is provided and challenges and opportunities of prospective distribution grids are summarized.

1.1.4 Public workshop on SmartNet project (T.2)

T. Gómez. Public workshop on SmartNet project. Advisory Board. Brussels, Belgium. June 20, 2018.

1.1.5 Analysis of storage and water value in power systems for policymaking on renewable energies (T1.1)

D.A. Tejada, A. Siddiqui, S. Wogrin, E. Centeno, Analysis of storage and water value in power systems for policymaking on renewable energies, 29th European Conference on Operational Research – EURO 2018. Valencia, Spain, July 08-11 2018.

Abstract: As variable Renewable Energy Source (vRES) production, e.g., solar and wind, increases, additional Energy Storage (ES) capacity may be desirable in order to manage vRES intermittency. Moreover, since Battery Energy Storage Systems (BESS) cost is expected to decrease in the next 10 to 15 years, intra-day storage, e.g., BESS, dispatch could affect inter-day storage, e.g., hydropower, dispatch and its opportunity costs, i.e., water value. Existing medium- or long-term hydrothermal dispatch models provide the water value only on a weekly or monthly basis and, consequently, neglect hourly water-value signals due to this coarse time resolution. However, short-term BESS decisions in energy and reserve markets have an impact on the water value (or opportunity cost) of long-term storage and should be reflected with a higher degree of precision. We develop a novel, computationally tractable framework for hydro thermal coordination in which hourly storage values (short-term signals) are co-optimized with seasonal storage (long-term water value signals). Thus, hourly opportunity costs, i.e., storage and water values, for inter- and intra-day storage can be obtained considering both short and long-term signals. We analyze a reduced version of Spanish power system, and the results are used to identify possible policy drivers for ES and vRES investments considering the interaction of inter- and intra-day storage.

1.1.6 Optimizing storage allocation and investment for transmission constrained networks considering losses and high renewable penetration (T1.1)

S. Wogrin, D.A. Tejada, D. Yacar, Optimizing storage allocation and investment for transmission constrained networks considering losses and high renewable penetration, 29th European Conference on Operational Research – EURO 2018. Valencia, Spain, July 08-11 2018.

Abstract: This work investigates the effects of transmission losses, constraints and increased renewable energy penetration on planning energy storage allocation and investment. By modifying a DC Optimal Power Flow model using a linearized approximation for Ohmic losses we were able to understand which network characteristic or inhibitor drives the most change in expanding utility scale storage. Four different storage technologies were explored—Compressed Air Energy Storage, Pumped

Hydro Storage, Lithium-Ion Battery and Fly Wheel—each having different charging, capacity and cost characteristics. The results of the storage allocation trials revealed that network congestion was a more influential network inhibitor than were line losses. Losses only had substantial effects on a free-flowing network but produced marginal changes in allocation in congested ones. The conclusion of the investment trials revealed two things: 1) Storage investment is not significantly affected by transmission constraints so long as renewable generation stays constant and relatively low; 2) More flexible technologies like Fly Wheels are favored at lower volumes of renewable penetration for their load balancing abilities while cheaper technologies are best as the volume of renewable power generated increase and become the majority of grid power.

1.1.7 Hierarchical Optimization and Equilibrium Problems in Electricity Systems: Challenges and Status Quo (T.2)

Sonja Wogrin. Hierarchical Optimization and Equilibrium Problems in Electricity Systems: Challenges and Status Quo. Isaac Newton Institute. Electricity systems of the future: incentives, regulation and analysis for efficient investment. Cambridge, UK. March 20, 2019. (Workshop)

The liberalization of the electricity sector and the introduction of electricity markets have greatly complicated the organization of the electricity sector, especially for generation companies. Under a centralized framework a central planner took decisions maximizing social welfare, whereas in electricity markets the responsibility of taking many decisions, such as generation expansion for example, lies with the generation companies. From a game-theoretic point of view many decision-making problems in a liberalized power sector can be regarded and analyzed as a game among strategic competitors in search of equilibrium solutions. Timing of decisions, or better yet, the sequence in which decisions are taken, can convert simple equilibrium games into complicated hierarchical equilibrium problems whose outcomes can diverge significantly depending on the type of game. This talk discusses two applications of such hierarchical games in electricity markets: generation expansion planning; and, generation flexibility in ramp rates. The results indicate that the market structure, i.e., the set-up of the game, can drastically influence outcomes.

1.1.8 Addressing flexibility issues in clustered unit commitment formulations for generation expansion planning models (T.1)

D.A. Tejada, G. Morales-España, S. Wogrin, E. Centeno. 30th European Conference on Operational Research – EURO 2019. Dublin, Ireland. 23-26 June 2019.

Abstract: This letter proposes a clustered unit commitment (CUC) formulation to accurately model flexibility requirements such as ramping, reserves, and startup/shutdown constraints. The classic CUC intrinsically and hiddenly overestimates the individual unit's flexibility, thus being unable to replicate the result of the individual

UC. This letter presents a set of constraints to correctly represent the units' hidden flexibility within the cluster. Different case studies show that the proposed CUC replicates the results of the individual UC while solving significantly faster. Therefore, the proposed CUC correctly represents the individual unit's flexibility within the cluster and could be used in large-scale planning models without significantly increasing their computational burden.

1.1.9 What is the cost of disregarding market feedback in transmission expansion planning? (T.2)

I.C. González Romero, S. Wogrin, T. Gómez. Smart Energy Systems and Technologies – SEST 2019. Oporto, Portugal. 9-11 September 2019.

Abstract: Under the current European market environment, transmission companies have to decide network expansion by maximizing social welfare. However, generation companies (GENCOs) decide their capacity expansion with the aim of maximizing their own profit. This process, in addition to the increasing penetration of renewable energy, storage and distributed generation, might represent a rupture between short and long-term signals. Therefore, this paper proposes a bi-level formulation for the generation and transmission coordination problem (GEPTEP). We consider a proactive framework in which a centralized TSO represents the upper level while the decentralized GENCOs, that trade in the market, represent the lower level. A case study is presented to evaluate different policy planning objectives. Additionally, the planning results of the bilevel framework (considering both perfect competition and Cournot oligopoly in the lower level) are compared with a traditional cost minimization framework.

1.1.10 What time-period aggregation method works best for power system operation models with renewables and storage? (T.1.1)

S. Wogrin, D.A. Tejada-Arango, S. Pineda, J.M. Morales. Smart Energy Systems and Technologies – SEST 2019. Oporto, Portugal. 9-11 September 2019.

Abstract: In this paper we compare two cutting-edge time-period aggregation methodologies for power system models that consider both renewables and storage technologies: the chronological time-period clustering; and, the enhanced representative period approach. Such methodologies are used in order to reduce the computational burden of highly complex optimization models while not compromising the quality of the results. With this paper, we identify which method works best, and under which conditions, in order to reproduce the outcomes of the hourly benchmark model.

1.1.11 Considering market feedback in transmission expansion planning with storage and renewable technologies (T.2.2)

I.C. González Romero, S. Wogrin, T. Gómez. 13th Trans-Atlantic Infraday (TAI). Washington D.C., USA. 17-18 October 2019.

Abstract: Under the current European market environment, transmission companies have to decide network expansion by maximizing social welfare. However, generation companies (GENCOs) decide their capacity expansion with the aim of maximizing their own profit. This process, in addition to the increasing penetration of renewable energy, storage and distributed generation, might represent a rupture between short and long-term signals. Therefore, this paper proposes a bi-level formulation for the generation and transmission coordination problem (GEPTEP). We consider a proactive framework in which a centralized TSO represents the upper level while the decentralized GENCOs, that trade in the market, represent the lower level. A case study is presented to evaluate different policy planning objectives. Additionally, the planning results of the bilevel framework (considering both perfect competition and Cournot oligopoly in the lower level) are compared with a traditional cost minimization framework.

1.1.12 Analyzing Time Period Aggregation Methods for Power System Investment and Operation Models with Renewables and Storage (T.1.2)

S. Wogrin, D.A. Tejada-Arango, S. Pineda, J.M. Morales. INFORMS Annual Meeting. Seattle, USA. 20-23 October 2019.

Abstract: In this paper we compare two cutting-edge time-period aggregation methodologies for power system models that consider both renewables and storage technologies: the chronological time-period clustering; and, the enhanced representative period approach. Such methodologies are used in order to reduce the computational burden of highly complex optimization models while not compromising the quality of the results. With this paper, we identify which method works best, and under which conditions, in order to reproduce the outcomes of the hourly benchmark model.

1.2 Software implementation of proposed models and prototyping (T.4.2)

For the different tasks of the project three different prototypes have been developed.

- Representative Days Prototype
  This prototype solves the co-optimization problem of energy storage technologies. It considers four execution types. a) System states method. b) Representative days method. c) system states reduced frequency matrix d)

Representative periods with transition matrix and cluster indices. This prototype is coded in GAMS

- Cost Minimization Benchmark Model
  This prototype solves the co-optimization problem for generation and transmission expansion planning. It considers three execution types. a) Without the consideration of Unit Commitment variables. b) With consideration of binary Unit Commitment variables. c) With the consideration of relaxed binary variables. This prototype is coded in GAMS.

- European Case
  This prototype solves a bi-level capacity expansion problem, it considers TRANSCO to take decisions first and GENCOs react strategically to these decisions. The prototype allows both perfect and imperfect competition executions. This model is coded in GAMS. The data corresponds to a Europe-wide case study.

- Spanish Case
  This prototype solves a bi-level capacity expansion problem, it considers TRANSCO to take decisions first and GENCOs react strategically to these decisions. The prototype allows both perfect and imperfect competition executions. This model is coded in GAMS. The data corresponds to a Spain-wide case study.

1.3 Dissemination via scientific articles (T4.3)

Scientific articles regarding the novelties of the proposed modeling approaches, and the subsequent policy results have been and will be written for their possible publication in high-rank scientific journals. The purpose of these articles is to disseminate the obtained progress in modeling and policy questions among researchers on an international scale. Bellow we can see the current publications: two published paper and two under review and a working paper.

1.3.1 Enhanced representative days and system states modeling for energy storage investment (T1.1)

D.A. Tejada, M. Domeshek, S. Wogrin, E. Centeno. Enhanced representative days and system states modeling for energy storage investment. IEEE Transactions on Power Systems.

Abstract: This paper analyzes different models for evaluating investments in Energy Storage Systems (ESS) in power systems with high penetration of Renewable Energy

Sources. First of all, two methodologies proposed in the literature are extended to consider ESS investment: a unit commitment model that uses "System States" (SS) method of representing time; and another one that uses a "representative periods" method. Besides, we propose two new models that improve the previous ones without a significant increase of computation time. The enhanced models are 'SS Reduced Frequency Matrix' model which addresses short-term storage more approximately than the SS method to reduce the number of constraints in the problem, and "Representative Periods with Transition Matrix and Cluster Indices" (RP-TM&CI) model which guarantees some continuity between representative periods, and introduces long-term storage into a model originally designed only for the short term. All models are compared using an hourly unit commitment model as benchmark. While both SS models provide an excellent representation of long-term storage, their representation of short-term storage is frequently unrealistic. RP-TM&CI model, on the other hand, succeeds in approximating both short- and long-term storage, which leads to almost 10 times lower error in storage investment results.

1.3.2 Policy implications of downscaling the time dimension in power system planning models to represent variability in renewable output (T1.1)

L. Reichenberg, A. S. Siddiqui, and S. Wogrin. Policy implications of downscaling the time dimension in power system planning models to represent variability in renewable output. Energy.

Due to computational constraints, power system planning models are typically unable to incorporate full annual temporal resolution. In order to represent the increased variability induced by large amounts of variable renewable energy sources, two methods are investigated to reduce the time dimension: the integral approach (using typical hours based on demand and renewable output) and the representative days method (using typical days to capture annual variability). These two approaches are tested with a benchmark implementation that incorporates full time representation in order identify their suitability for assessing power systems with high renewable penetration. The integral method predicts renewable capacities within a 10% error margin, this paper's main performance metric, using just 32 time steps, while the representative days approach needs 160–200 time steps before providing similarly accurate renewable capacity estimates. Since the integral method generally cannot handle variation management, such as trade and storage, without enhancing the state-space representation, it may be more applicable to one-node models, while the representative days method is suitable for multi-regional models. In order to assess power systems with increasing renewable policy targets, models should be designed to handle at least the 160 time steps needed to provide results that do not systematically overestimate the renewable capacity share.

1.3.3 Storage Allocation and Investment Optimization for Transmission Constrained Networks Considering Losses and High Renewable Penetration (T1.1)

D. Yacar, D.A Tejada-Arango, S Wogrin. Storage Allocation and Investment Optimization for Transmission Constrained Networks Considering Losses and High Renewable Penetration. (Under Review IET)

This paper investigates the effects of transmission losses, constraints and increased renewable energy penetration on planning energy storage allocation and investment. By modifying a DC Optimal Power Flow model using a linearized approximation for ohmic losses we were able to understand which network characteristic or inhibitor drives the most change in expanding utility scale storage. Four different storage technologies were explored: Compressed Air Energy Storage, Pumped Hydro Storage, Lithium-Ion Battery and Fly Wheel. Each had different charging, capacity and cost characteristics. The results of the storage allocation trials revealed that network congestion was a more influential network inhibitor than were line losses. Losses only had substantial effects on a free-flowing network but produced marginal changes in allocation in congested ones. The conclusion of the investment trials revealed two things: 1) Storage investment is not significantly affected by transmission constraints so long as renewable generation stays constant and relatively low; 2) More flexible technologies like Flywheels are favoured at lower volumes of renewable penetration for their load balancing capabilities while cheaper technologies are best as the volume of renewable power generated increases.

1.3.4 Proactive transmission expansion planning with storage considerations (T2.2)

I.C González-Romero, S. Wogrin, T. Gómez. Proactive transmission expansion planning with storage considerations. (Submitted for review in “Strategy Energy Reviews”).

Abstract: Under the current European market environment, transmission companies (TRANSCOs) have to decide network expansion by maximizing social welfare. However, generation companies (GENCOs) decide their capacity expansion with the aim of maximizing their own profit. This process, in addition to the increasing penetration of renewable energy, storage and distributed generation, might represent a rupture between short and long-term signals. Therefore, this paper proposes a bi-level formulation for the generation and transmission coordination problem (GEPTEP). We consider a proactive framework in which a centralized TRANSCO represents the upper level while the decentralized GENCOs, that trade in the market, represent the lower level. As a novel feature, an enhanced representative period framework is employed, which allows us to consider operation in both short and long-term storage technologies. A case study is presented to compare the results between perfect and imperfect competition in the market.

1.3.5 Opportunity cost including short-term energy storage in hydrothermal dispatch models using a linked representative periods approach (T1.2)

D.A. Tejada-Arango, S. Wogrin, E. Centeno. Opportunity cost including short-term energy storage in hydrothermal dispatch models using a linked representative periods approach. Energy.

Short-term energy storage systems, e.g., batteries, are becoming one promising option to deal with flexibility requirements in power systems due to the accommodation of renewable energy sources. Previous works using medium- and long-term planning tools have modelled the interaction between short-term energy storage systems and seasonal storage (e.g., hydro reservoirs) but despite these developments, opportunity costs considering the impact of short-term energy storage systems in stochastic hydrothermal dispatch models have not been analysed. This paper proposes a novel formulation to include short-term energy storage systems operational decisions in a stochastic hydrothermal dispatch model, which is based on a Linked Representative Periods approach. The Linked Representative Periods approach disposes of both intra- and inter-period storage constraints, which in turn allow to adequately represent both short- and long-term storage at the same time. Apart from the novelty of the model formulation itself, one of the main contributions of this research stems from the underlying economic information that can be extracted from the dual variables of the intra- and inter-period constraints, which allows to derive an hourly opportunity cost of storage. Such a detailed hourly economic value of storage has not been proposed before in the literature and is not possible in a classic Load Duration Curve model that does not adequately capture short-term operation. This advantage is reflected in the case study results. For instance, the model proposed in this paper and based on Linked Representative Periods obtains operating decisions of short-term energy storage systems with errors between 5% to 10%, while the classic Load Duration Curve approach fails by an error greater than 100%. Moreover, the Load Duration Curve model cannot determine opportunity costs on an hourly basis and underestimates these opportunity costs of hydro (also known as water value) by 6% to 24% for seasonal hydro reservoirs. The proposed Linked Representative Periods model produces an error on the opportunity cost of hydro units lower than 3%. Hourly opportunity costs for short-term battery energy storage systems using dual variables from both intra- and inter-period storage balance equations in the proposed model are also presented and analysed. The case study shows that the proposed approach successfully internalizes both short- and long-term opportunity costs of energy storage systems. These results are useful for planning and policy analysis, as well as for bidding strategies of ESS owners in day-ahead markets and not taking them into account may lead to infeasible operation or to suboptimal planning.

1.3.6 A review on Generation and Transmission Expansion Co-planning Under a Market Environment (T2.2)

I.C González-Romero, S. Wogrin, T. Gómez. A review on Generation and Transmission Expansion Co-planning Under a Market Environment. IET Generation Transmission Distribution.

This paper presents a review of the state of the art on the coordination of generation and transmission expansion planning. First, we present the different modelling approaches to represent transmission and generation operation and investment in generation and transmission expansion models, with an emphasis on the co-optimisation problem. Second, a comprehensive review on co-planning equilibrium models in a market environment is carried out. We consider that centralized (in some cases decentralized) transmission companies take network expansion decisions while decentralized generation companies decide their capacity expansion. Compared with previous works, we carry out a detailed classification of equilibrium models. We explicitly differentiate their hierarchical and regulatory structure with their equivalent reduced structure (after the application of level reduction methodologies to solve the equilibria). Additionally, we classify the distinctive market approaches that usually represent the lower level of co-planning problems. Finally, we examine the existing investment and operation modelling options and we identify gaps in the literature of each one of the mentioned categories.

1.3.7 Power-based generation expansion planning for flexibility requirements (T1.1)

D.A. Tejada, G. Morales-España, S. Wogrin, E. Centeno. IEEE Transactions on Power Systems.

Flexibility requirements are becoming more relevant in power system planning due to the integration of variable Renewable Energy Sources (vRES). In order to consider these requirements Generation Expansion Planning (GEP) models have recently incorporated Unit Commitment (UC) constraints, using traditional energy-based formulations. However, recent studies have shown that energy-based UC formulations overestimate the actual flexibility of the system. Instead, power-based UC models overcome these problems by correctly modelling ramping constraints and operating reserves. This paper proposes a power-based GEP-UC model that improves the existing models. The proposed model optimizes investment decisions on vRES, Energy Storage Systems (ESS), and thermal technologies. In addition, it includes real-time flexibility requirements, and the flexibility provided by ESS, as well as other UC constraints, e.g., minimum up/down times, startup and shutdown power trajectories, network constraints. The results show that power-based model uses the installed investments more effectively than the energy-based models because it more accurately represents flexibility capabilities and system requirements. For instance, the power-based model obtains less investment (6-

12%) and yet it uses more efficiently this investment because operating cost is also lower (2-8%) in a real-time validation. We also propose a semi-relaxed power-based GEP-UC model, which is at least 10 times faster than its full-integer version and without significantly losing accuracy in the results (less than 0.2% error).

1.3.8 A decentralized solution for Transmission Expansion Planning: getting inspiration from nature (T.2)

S. Lumbreras, S. Wogrin, G. Navarro, I. Bertazzi, M. Pereda. A decentralized solution for Transmission Expansion Planning: getting inspiration from nature. Energies.

Transmission Expansion Planning is a problem of considerable complexity where classical optimization techniques are unable to handle large case studies. Decomposition and divide-and-conquer strategies have been applied to this problem. We propose an alternative approach based on Agent-Based Modeling (ABM) and inspired by the behaviour of the Plasmodium mold, which builds efficient transportation networks as result of its search for food sources. Algorithms inspired by this mold have already been applied to road network design. We modify an existing ABM for road-network design to include the idiosyncratic features of power systems and their related physics, and test it over an array of case studies. Our results show that the ABM can provide near-optimal designs in all the instances studied, possibly with some further interesting properties with respect to the robustness of the developed design. In addition, the model works in a decentralized manner, using mostly local information. This means that computational time will scale with size in a more benign way than global optimization approaches. Our work shows promise in applying ABMs to solve similarly complex global optimization problems in the energy landscape.

1.3.9 Transmission expansion planning under imperfect market competition: social planner versus merchant investor (T2.2)

I.C González-Romero, S. Wogrin, T. Gómez. Transmission expansion planning under imperfect market competition: social planner versus merchant investor. (Sent to Energy Economics).

The growing penetration of renewable technologies, as well as the increasing need for storage technologies, comprise new challenges for electricity market design. In this context, decentralized generation companies decide their investments by maximizing their own profit, while centralized TSOs decide network expansion, by aiming to maximize the overall social welfare. This already challenging environment is further complicated by renewables intermittency and the short-and long-term dynamics of storage technologies, which may permit generation companies to exercise new forms of market power. However, traditional (and widely utilized) cost minimization planning models do not account for this type of strategic interactions. As an alternative, we present a bi-level proactive transmission framework, in which a centralized TSO takes

network investment decisions by anticipating the reaction of decentralized generation companies. Additionally, we consider a transmission merchant investor, and we investigate the planning and welfare results compared to those of a social planner. Finally, we study the policy implications of planning the system under a traditional cost-minimization approach, instead of a proactive framework that accounts for distinctive technology ownership structures, as well as distinctive degrees of competition. We carry out a comprehensive analysis of a 3-node case, and we extract more general insights from an IEEE 24-node case.

1.3.10 On the proper use of Net Present Value for Capacity Expansion Planning with Renewable Generation with Decreasing Investment Cost (T1.1)

E. Centeno and S. Wogrin. On the proper use of Net Present Value for Capacity Expansion Planning with Renewable Generation with Decreasing Investment Cost. (Working paper)

Generation investment cost are significantly decreasing for some renewable technologies as wind power, making them favorites for generation capacity expansion. Nevertheless most of the capacity expansion models commonly used, either consider a single year in the future, either consider a set of them but annualizing investment costs, arbitrarily distributing them along the plant life-span. This approach may be misleading if investment cost varies along the years. This paper presents a deterministic cost minimization model for capacity expansion planning under the infinite life hypothesis of companies, taking into account at the same time finite life span of assets by properly including residual value and considering overall investment costs (overnight costs).

This model distributes the recovery cost along the years in an optimal way. It is compared with a model where investment costs are uniformly annualized. It is also shown that under certain hypothesis the models are obtaining the point where the company breaks even (net present value equals zero if it is discounted with the weighted average capital cost of the company). When recovery cost is analyzed under the hypothesis of decreasing investment costs, cost recovery is preferred in the first years of the study horizon. These results suggest that uniform annualization may not be the most adequate alternative in this context. These results open the possibility of a deeper analysis of the optimal recovery cost path for any electrical asset taking into account uncertainty of renewable sources, demand elasticity, corporate taxes and network.

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