POLICY DIALOGUE ON

RENEWABLE GENERATION AND REGIONAL POWER TRADE IN AFRICA

READING FOR SESSION #3

TRANSMISSION COST ALLOCATION IN REGIONAL MARKETS

AFRICAN SCHOOL OF REGULATION

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1. Introduction

Power trade at regional level can exist under market conditions or by bilateral agreements between parties without the need for an organised market. Power pools existed in the 1970s in several regions in the USA or in Spain (1985), for instance, allowing power to be traded among several vertically integrated utilities without the existence of wholesale markets, which only began to appear in Chile (1982) and later in the UK (1990). The common feature of those power pools was the least cost centralized dispatch of electricity production resources, i.e., that the most efficient available generation units were employed to meet the aggregated power pool demand at all times (subject to transmission constraints). The participants in some power pools also developed joint capacity expansion plans of transmission and sometimes also of generation.

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Many cross-border regulatory arrangements are being employed throughout the African continent at bulk power system level, generally without competitive markets at national level. Some regions like Southern Africa and more recently West Africa have implemented regional markets at different levels of development. Given this diversity of situations, this document will avoid using the term "market" when referring to common general situations in Africa and will use the term "power system organisational structures" instead, as recommended by IRENA recently.[2]

This technical note applies to all regional power system structures existing in Africa at bulk power system level, liberalised and regulated, because the main regional power trade challenges are common to all of them.

2. Regional trade and power pools

Large-scale integration or power resources can have a strong positive impact on the overall electrification process in the African continent, and in sub-Saharan Africa in particular. Superficially, regional trading of power seems to be a low-hanging fruit, since establishing an advanced power trading platform with sound rules and institutions does not require substantial expenses. It requires, though, the alignment of the involved governments and parliaments regarding giving up some sovereignty to the regional institutions – regional regulatory authority and regional operator – and the common acceptance of sound trading rules and sharing transmission utilization and cost. Development of these regulations requires specialized knowledge and their implications – although beneficial from the viewpoint of overall efficiency and facilitation of investment in generation and transmission – might enter into conflict with entrenched privileges of stakeholders in some of the countries.

Formally organized regional integration of power systems, i.e., regional power pools, can be an effective way to create economies of scale for mobilizing private-sector investments, leverage synergies related to demand and supply and advance economic integration. When properly designed and implemented, regional power pools can lower the cost of electricity supply and improve the quality of delivered electricity services, thereby driving socio-economic development. Power pools provide these benefits when they include regional-scale generation plants and adequate cross-border transmission infrastructure. These prerequisites can only be met under sound power pool rules and governance.

Regional power pools are particularly relevant in the specific context of sub-Saharan Africa, both because the size of the national power system in at least 20 countries in this region is presently below the efficient level of output for a single power plant and because some countries have sufficient renewable resources (e.g., hydro, geothermal, or solar) to not only meet domestic demand but to also export excess power. Five power pools have been established in SSA – West, East, Central and South, which have very different levels of development – as well as the organization coordinating the efforts to facilitate the trading of power among five North African countries (Comité Maghrébin de l'Électricité, COMELEC), also in collaboration with several Southern European countries.

The potential of these power pools remains largely untapped due to technical and political barriers. Effective power pools require a strong alignment of interest among participating countries and external partners, including private entities and financing institutions that are willing to invest in regional infrastructures under the right conditions. National-level political commitment is needed to

[2] The term "power system organisational structures" can be used to refer to the systems, institutions, procedures and social relations through which electricity services are exchanged and rewarded. It encompasses all systems, from liberalised power systems (based primarily on market mechanisms) to vertically integrated systems. For a liberalised power system, the term "power market" is equivalent to "power system organisational structure". See IRENA (2022), "Re-organising power systems for the transition", International Renewable Energy Agency, Abu Dhabi.

give executive responsibilities and resources to regional institutions, identify barriers and vested interests that impede progress, and build the capacity to regulate and operate regional systems.

The main obstacles to achieving the benefits of power pools are well known: ineffective regional governance and flaws in the rules for regional trading and network cost allocation. Both discourage investments in transmission infrastructure and regional-scale generation plants, especially when combined with a lack of trust among states, a lack of willingness to liberalize markets, concerns over the preservation of national autonomy and sovereignty and a preference for bilateral contracts over regional agreements.

2.1. Regional governance

Securing the low-cost power needed to drive industrialization and economic growth is a priority for the governments of all countries. In SSA, while many countries struggle with insufficient or unreliable power, others are beginning to worry about excess capacity. It is becoming increasingly clear to them that a challenge on this scale requires a regional as well as a national approach, and that trading power is of the essence. Complex coordination both within and among countries is required in investment, regulations, and system operations and this will only be possible with political leadership.

Despite potential benefits, regional integration is frequently hampered by the absence of strong regional institutions and enabling regulations. Existing power pools generally lack executive powers and capacity in two key regional institutions: the system operator and the regulator. This undermines regional transmission planning and operation and results in poor regulatory harmonization.

2.2. The rules of regional trade and transmission cost allocation

The guiding principle in the design of a regional power pool is the "single system paradigm" – that is, the principle that a regional power pool must function as close as possible in its operation and planning decisions, transmission regulation and governance to a single country of the corresponding regional dimension. In practice, loss-of-sovereignty concerns and implementation issues severely limit the application of this principle.

When existing power pool rules fall short of this ideal, the efficiency and security of supply deteriorate. For instance, in the SSA power pools, current physical bilateral contracts distort the economic dispatch of generation and demand. The 2020-2023 WAPP Master Plan says: "Indeed, up to now, contracts for the exchange of electricity between States are subject to bilateral agreements with a fixed rate for a long period and are monitored by a meter on the interconnection line. These contracts that proved their value in a radial market could be ineffective or sub-optimal in a large interconnected and meshed network in which all generation options should be able to compete."

2.3. Transmission investment, pricing and access

Sound transmission regulation is critical to successful power pools. Transmission, which contributes a relatively small part of the overall cost of the sector value chain, needs to move in tandem with additions to generation capacity. Transmission lines reduce overall costs by ensuring economies of scale in generation; creating access to cost-efficient sources of generation; reducing the reserves needed to ensure security of supply; and supporting the integration of renewables into the energy system. Even so, transmission remains a neglected part of the sector value chain.[3]

[3] The length of transmission lines in Africa is 220 km per million people (excluding South Africa). In contrast, Colombia has 295km of transmission lines per million people, Peru has 339km, Brazil has 610km, Chile has 694km, and the United States has 807km. 9 countries in SSA have no transmission lines above 100 kV. The combined length of transmission in 38 countries in Africa is 112,196 km. The country of Brazil has a longer transmission network than Africa, at 125,640 km, and, at 257,000 km, the United States of America (United States) has more than twice the length of the African transmission network. Despite its large land mass, Africa also has fewer kilometers of transmission lines per capita than other regions. See GRIDS4Africa, "Private Sector

Building more transmission lines and upgrading transmission capacity will be an essential part of the overall expansion of the African electricity sector. And this can only be done by attracting massive private investment. Presently almost all transmission investment in Africa is financed by state-owned enterprises. The estimates of annual investments required for transmission in Africa until 2040, range from US$3.2 billion to US$4.3 billion, which will not be possible to raise with public funds.

A prerequisite to attract private investment is a sound transmission regulation: the institutions, criteria, procedure and enforcement of regional transmission planning; the determination of transmission cost and the allocation of this cost to the agents of a regional organisation structure; and the rules to share the use of the existing limited transmission capacity in the real time operation of the power system.

Regional transmission planning requires a technically capable regional system operator and the means of enforcing that what has been planned at regional level will be finally built by the countries, which in territorial issues always have the last word. A workable system of checks and balances is necessary so that the transmission investments that have been identified as socially beneficial from a regional perspective will be accepted by the individual counties in whose territories the lines must be built.

A key aspect in this multi-party negotiation is that every country perceives that the benefit accrued to the country by a transmission investment is larger than the fraction of the cost of the investment that the country will have to pay. This brings to the fore the always conflictive issue of transmission cost allocation in a regional context.

The absence of sound, commonly-agreed procedures to allocate transmission costs will deter potential investors as it increases the risk of not receiving sufficient economic compensation. Inadequate charges for cross-border transactions that use regional interconnections will stifle trade until sound transmission pricing rules are implemented. Moreover, power-pool-wide congestion management rules are needed to establish priorities in the efficient use of scarce network capacity.

This technical note discusses the rules for the allocation of transmission costs in African power pools and offers recommendations to overcome the present shortcomings, making use of the best widely-accepted international practices. A companion paper deals with the capabilities and performance of regional institutions, and another one with the efficient operation of generation and demand resources at regional scale.

3. Transmission cost allocation principles and implementation guidelines

A sound regulation of transmission cost allocation should meet the following self-explanatory objectives:

i) Facilitate investment in transmission by reducing as much as possible any economic justification for the stakeholders to oppose a socially beneficial transmission project because they are negatively impacted by it.

ii) Promote investment in generation by reducing the risk of uncertainty in the value of future transmission charges.

iii) Avoid charging unjustified large fees to those agents located in one country who happen to establish bilateral contracts with agents in other countries, since this will impede efficient trade.

iv) Avoid distorting the operation (short-term) decisions of the agents of the power system (see bullet vii in section 4 below).

Participation in African Grid Development", https://www.res4africa.org/grids4africa and World Bank Group. 2017. "Linking Up : Public-Private Partnerships in Power Transmission in Africa." World Bank, Washington, DC. © World Bank. https://openknowledge.worldbank.org/handle/10986/26842

The existence of a common approach at regional level to allocate the costs of regional transmission infrastructure is another highly desirable objective. However, the reality of regional organisations in Africa must be acknowledged, and it is also an objective not to create difficulties in the development of necessary transmission projects when the regional transmission regulation is not ready yet. This technical note proposes a method to make compatible these two objectives.

3.1. General principles of transmission cost allocation

These objectives can be accomplished by designing cost allocation rules that stay as close as possible to the three fundamental principles that must underly any transmission cost allocation method:[4]

- Transmission costs should be allocated to the beneficiaries of the transmission assets.
- Transmission charges should not depend on the commercial transactions among the power system agents.
- Transmission charges should be announced a priori and for a long period of time, so that economic risk for the agents is reduced and any locational signals are effective.

The implementation of these high-level principles opens a large number of other topics that need to be carefully addressed. Most of them apply both at regional and national levels. They are listed and briefly commented on below.

3.2. General implementation guidelines

Successful design and implementation of large transmission projects require abiding by the following general cost allocation rules:

i) Transmission cost allocation is about how the costs of the project will be assigned to the different participating agents that use or benefit from the transmission project. Two items must be clearly differentiated:

- *Financing the total costs of the project.* The project costs have to be financed by the project promoters, for instance via some kind of Special Purpose Vehicle (SPV) for the specific project. The actual costs are incurred when the investments are made and continue with additional minor investments, plus the operation, maintenance and administrative costs. These actual costs have to be financed with grants, debt and equity of different types, resulting in payments made by the SPV to the financing entities, in quantities and times previously specified in the financing agreements. The trajectory in time of the financial costs is typically very irregular, since most of the investment costs happen during the installation of the transmission network assets, i.e., during the first few years of the economic life of the project.
- *Payment of the cost of the project by its users/beneficiaries.* The users/beneficiaries of the project have to make payments – the "use-of-transmission charges" – to the SPV, so that the SPV can meet their obligations with the financial entities and incur in all the other costs of the project. The charges to the users/beneficiaries of the project will be determined by some cost allocation method. The countries may act as intermediaries in this process, with their regulators establishing the transmission component of the regulated tariffs to the users/beneficiaries that will allow for recovering the transmission costs.

ii) Transmission costs only include the costs of investment and the cost of operating and maintaining the equipment. None of these costs depends on the level of utilization of the

[4] See Pérez-Arriaga, I.J. editor, "Regulation of the Power Sector", Springer, 2013, https://www.springer.com/gp/book/9781447150336 and the MIT report "The Future of the Electric Grid", https://energy.mit.edu/wp-content/uploads/2011/12/MITEI-The-Future-of-the-Electric-Grid.pdf

transmission facilities. O&M costs can be roughly estimated as percentages of the investment costs, with different percentage values for each type of facilities. Losses and congestions happen in the transmission facilities, but they are not transmission costs; losses and congestions result in higher electricity production costs.

iii) When regulatory authorities determine the total amount of transmission charges (the so-called "revenue requirement") for a given year, they do it using accounting methods so that the annual amount (the annuity) does not change much from one year to the next, and therefore the trajectory of the transmission charges follows a smooth and predictable path over time. They also make sure that, over the economic (or regulatory) lifetime of the assets the present value of the annuities equals the present value of the actual incurred costs (perhaps including some efficiency or performance incentives), obviously including a reasonable remuneration of the invested capital and the debt service. This is a fundamental regulatory principle that must always be respected: the cost allocation method and the design of the transmission charges to be levied to the users/beneficiaries of the transmission activity must cover the recognized cost of this activity – the "transmission revenue requirement". The regulation must be designed so that transmission charges do not introduce unnecessary risks in the mechanism of recovery of the transmission revenue requirement.

iv) Another necessary clarification is the differentiation between "regional" and "national" transmission assets. The latter have negligible relevance in cross-border trade, while the former are needed to establish physical transfers of electric power among countries. Obviously, there is no clear separation between both categories and some threshold must be established in the regulation, based on engineering estimates and actual power flow patterns. Transmission lines that cross country borders are obvious candidates for regional transmission assets. Note, however, that many transmission lines that are purely internal to a country can have much relevance in regional power trade, for instance allowing the wheeling of power through this line between two other countries.

v) It is also important to distinguish between existing and new (planned) transmission assets. The importance of the cost allocation procedure stems from the potential opposition that a technically and economically sound transmission project may find by a country or important agent that considers it will have to pay more than the benefit obtained from the project, under some proposed cost allocation method. The consequences of this potential opposition are only important for new investments, obviously.

vi) How should the regulation apply to large new transmission projects? We have two major options.

A. Under the first option, a large transmission project would not be exempt from the general treatment for all transmission investments of regional type. This approach will certainly simplify regulation, as it will avoid dealing all the time with particular cases that will arise continuously as the transmission network and the physical flows become increasingly complex.

B. Under the second option, large transmission projects, which might be promoted by a coalition of large power sector players – would be exempted from the general rules, allowing the promoters and the future users to decide who pays for the use of these facilities, how much and for how long. This approach may facilitate the creation of consortia of promoters and the deployment of transmission investments, while multinational agreements on the market rules and cost allocation methods may take a long time to be agreed upon and implemented into practical regulation. However, this second approach will probably lead to chaos in the mid and long-term as the regional grid develops and these large projects become just one more component of a densely meshed transmission system.

As we shall see later, these two options may not be incompatible, if we accept to give up in other aspects, such as in the locational component of the transmission charges, and we accept the essential transmission cost allocation rule that "transmission charges should not depend on commercial transactions".

vii) It is desirable that transmission charges have some locational component, i.e., all other things being equal, those agents whose activity as producers or consumers makes necessary to add new transmission facilities must pay more than those that do not cause any stress or need for new reinforcements of the network. This is particularly important for large generators (or large concentrations of medium size or even small generators), because they typically have more siting freedom. Locational signals may guide new investors in generation to choose sites that avoid costly transmission investments. But it has to be decided first who the agents are to be charged the cost of transmission.

viii) Who are the agents to whom the costs of transmission must be allocated? First, one has to make an initial major design decision between two options:

A. The methodology of cost allocation of regional investments will be applied only at country level, leaving to each country how to include the total regional charge allocated to it in the use-of-transmission-network-charge component of the regulated tariffs within the country; or

B. There is the intention of introducing transmission charges with locational differentiation at nodal level in the regional network, i.e., different charges for agents connected at different nodes of the regional transmission network.

According to the first principle of transmission pricing, transmission charges must be levied upon the beneficiaries of a transmission project, which in a general case are both consumers and producers. Therefore, a priori radical decisions such as "only consumers shall pay for transmission" or "all transmission charges must be levied to producers" are not justified.

ix) Legal security dictates that the cost allocation rules must not be modified if possible, and only for a very good reason and with sufficient warning. However, the numerical results of the application of these rules will typically change, for instance when a new agent enters the system.

x) The regulatory authorities of each country must be responsible for setting the transmission component of the charges that apply to each system agent within this country. When computing these charges, the regulatory authorities must take into account the decision made on how to allocate the costs of the regional transmission network.

- Consider first the case where regional cost allocation is made at country level. Then the regulator will establish the transmission costs to be included in the regulated charges as follows: start with the costs of the transmission network within the country, then subtract the charges that might have been allocated to other countries for the use of the regional transmission network of the country, and add the charges allocated to this country because of its use of the regional network in other countries.

- Now consider the case where the costs of the regional transmission network have been allocated already to the generators and demands connected – either directly or indirectly – to each transmission network node. Our recommendation is to socialize – i.e., make uniform – the charges to consumers within the country, except perhaps for the largest consumers, since a transmission locational signal is not going to make any difference. On the other hand, the locational transmission charges for generators should be maintained.

xi) Congestion (i.e., lines reaching their maximum load carrying capacity under existing conditions and maintaining specified security levels) happens frequently in transmission networks.

Depending on the transaction rules at bulk power system level, many power systems collect "congestion rents" under these circumstances. The "collecting entity" is usually the System Operator, either at national or regional level. Given that the transmission revenue requirement is determined based on actual costs, and that congestions do not modify the cost of transmission, the best use of the congestion rents is to decrease the transmission revenue requirement to be charged to the network users/beneficiaries. Under no circumstance the congestion rents should augment the remuneration of transmission or of the system operators.

xii) Transmission investments are lumpy, and they last many years (i.e., 40 or more; actually, they are refurbished, but never removed). When they enter into service their load carrying capacity typically exceeds what is needed at that moment, i.e., there is a lot of idle capacity during the initial years. It does not seem cost-reflective to charge the total cost of a transmission investment to its users/beneficiaries when they are using/benefiting only from a fraction of the transmission capacity. Different approaches have been proposed to allocate these "residual costs".[5] In the context of transmission cost allocation, any simple method of socialization of the cost to demand can be considered acceptable.

xiii) Finally, it must be avoided to introduce risk in the remuneration of transmission unnecessarily. This requires that the rules to determine and allocate the transmission costs are clearly stated and that they do not create uncertainty themselves.

- For instance, if the investment in a transmission project has been made in a year T and the costs were incurred with the technologies and catalogue of components available in year T, the calculation in year T+N of the revenue requirement for that project should not be made based on the new technologies and costs of year T+N, since this creates an unmanageable risk for the transmission investor, resulting in a higher cost of capital and higher chargers for the users/beneficiaries.
- Another example is the deviation in the forecast of demand when determining the transmission tariffs. If the transmission component of the tariff or any transmission charges are defined in volumetric terms (USD per kWh consumed, for instance), the error in the estimation of the annual demand will result in a surplus or deficit in the collection of the transmission revenue requirement. This has to be accepted, as errors in the estimation of future demand cannot be avoided. However, this should not result in any uncertainty in the revenues of the transmission company, as the actual difference – positive or negative – can be easily included in the determination of the revenue requirement of transmission for the following year.

4. Recommendations on the agents to be subject to regional transmission charges

We start with the definition of the agents that will be subject to the transmission charges of the regional network. In bullet (vi) above, the two basic choices were described. According to option A, the allocation of the cost of a new regional transmission project must be done under a uniform set of rules, established by the regional regulator and implemented by the regional system operator, which would apply to any regional transmission asset in the entire region. On the other hand, option B would allow large transmission projects to have their own cost allocation rules. It happens that it is possible to design a cost allocation approach that eliminates the need to choose between these two alternatives. These are the main features of this approach, which we recommend:

[5] Pérez-Arriaga, J.I. et al. The MIT "The Utility of the Future" study, 2016. https://energy.mit.edu/wp-content/uploads/2016/12/Utility-of-the-Future-Executive-Summary.pdf

i) Establish that the charges of the regional transmission network will be applied at country level. Therefore, any locational component of the charges will only happen in a "diluted" form, i.e., at country level, and not at nodal level.[6]

ii) For a new important transmission project, let the involved countries decide how much is the corresponding revenue requirement and how to allocate this cost among them.[7] The rules that these countries agree should make sure that the total annual cost of transmission of the project is fully recovered each year with the established system of charges. The regional regulator will supervise that this is the case and also that the agreed revenue requirement is reasonable.

iii) If the countries do not manage to reach an agreement on how to allocate among them the costs of the transmission project after a prespecified time period, the decision will be made by the regional regulator, using whatever transmission cost allocation rules they have established and that have been approved for the system operator to implement.

iv) The allocation of the cost of the *existing* regional network will be done with the method approved by the regional regulator and implemented by the regional system operator, but in the end, the method must result in an allocation of the cost of this regional network to the countries, not to the nodes. Note that, while applying this procedure, the assets of the large projects that have been allowed to have their own allocation method must be assumed to have zero cost, i.e., are ignored for all economic purposes (this is needed to avoid double counting).

v) Once the allocation of the costs of the entire regional network for the considered year has been completed, each country can proceed to determine its internal transmission charges as described in the first sub-bullet of bullet (x) above.

Note that we have made the general method and the methods adopted for any exempted large projects allocate their costs at country level. This makes both methods compatible, since the costs obtained by each method can be just added. This solves the problem of the future chaos that could ensue should uncoordinated regulated and free allocation methods coexist, without any coordination among them.[8]

There is another advantage of charging countries, which must be represented by some institution: the national System Operator (SO) would be the preferred option, if there is one, or the national public utility, or utilities. Project promoters want to make sure that the charges are levied on the utilities, since this seems to provide more guarantee of cost recovery than passing the recovery of transmission costs to national tariffs, where there is collection risk because of non-payments or illegal connections.

vi) In the implementation of this process, it is recommended that countries are represented by their (independent) system operators, when they exist. Otherwise by their national electricity companies. The actual implementation concerning the regional transmission network will be

[6] This is the method adopted in the Internal Electricity Market of the European Union. The Mercado Eléctrico Regional (Regional Electricity Market) in Central America uses the nodal charge approach.

[7] Some engineering method based on analysis of flow patterns must be used to determine which are the countries involved. Alternatively, the promoting countries decide to allocate the costs only among themselves. Any future charges to other countries should be based on the general rules established by the regional regulator and applicable throughout the region.

[8] An important observation: It would be also conceptually possible – although difficult in practice – to agree that the uniform centralized method and any method developed by an exempt transmission project must both allocate the costs at nodal level, in nodes of the regional network. Then the charges obtained by any method could also be added at each node. The danger here is the use of flawed designs of cost allocation methods (for instance those based on commercial transactions), whose errors may cause distorted charges that may jeopardize efficient trade. No problem if sound methods are used.

the responsibility of the regional system operator, under the supervision of the regional regulator

vii) The choice of format of the transmission charge, i.e., whether it is charged as a lump sum once per year or included in the regulated tariff – just added to its volumetric component ($/kWh) – or proportional to the nominal capacity of the generation plants ($/kW) or to the contracted capacity of a consumer, is important, since it will have an impact on the behaviour of the agents. For instance, a volumetric charge ($/kWh) for a generator is proportional to its annual energy production and it must be considered by the generator as an additional variable production cost, therefore with impact in its merit order in an optimal economic dispatch. It is advisable that transmission charges to generators be applied as an annual sum whose value cannot be directly related to actual production volume.

5. Recommendations for the adoption of a quantitative method to allocate the cost of a regional network

Once the regional transmission network has been identified, a single common method – i.e., one that applies all over the region, for cross-border lines and for regional lines internal to a single country – is needed to allocate the costs of all these assets to the countries. Note that we have accepted that some large projects, can have their own cost allocation methods, which must allocate the costs to the countries, and not to network nodes or individual generators or loads. Now we shall focus on the design of the uniform regional method, which, if well-conceived, could also serve as a model for the cost allocation method of any exempt large transmission project.

Note that – as already indicated above – if the purpose of the transmission tariff is to recover the acknowledged cost of the transmission activity (i.e., its regulated revenue requirement), one must realize that losses and congestions *happen* in the transmission facilities, but they are not transmission costs. The investment, operation and maintenance costs of transmission facilities do not depend on whether the lines are congested or not, or whether the wires are hot or cold because of losses or another factor. Losses and congestion rents must not have an impact on the revenue requirement of transmission or the revenues of the system and market operator.

Again, bringing here a point already made, given that the transmission facilities were built during some year T at the cost of that year T, remunerating the transmission company using the replacement values of these assets in some future year creates an unnecessary financial risk for the transmission investor, which, no doubt, will be reflected in its cost of capital and subsequently in the transmission tariffs.

5.1. Recommending a cost allocation method

The "first best" method. Allocation to beneficiaries

The "first best" method to allocate the cost of a substantial transmission project is to charge the beneficiaries of the project in proportion to the estimated benefits of each one. Since it has been decided above that the allocation will be done to the countries, the benefits accruing to each country because of the considered transmission investment will have to be estimated. Since the project is expected to have a long useful life, the benefits must be estimated during a long-term period.

What are these benefits? In principle the economic benefits of more income for generators and/or lower cost of electricity to consumers in each country. If the investment in the transmission project has been found to be well justified, the aggregated benefits for all countries must clearly exceed the cost of the project over its lifetime and the allocation of costs in proportion to the benefits must leave every country satisfied. A few countries, however, may be net losers and it may be decided by the ensemble of the agents to compensate them so that they remain at least neutral, or to pay them a small compensation negotiated with the others.

In this context, the concept of "benefit" can be interpreted more broadly than in terms of economic income or payments. A transmission project can make possible the utilization of energy resources that otherwise would have remained idle, or it can increase the size or the liquidity in a regional wholesale market, or it can mitigate market power by making possible the competitive utilisation of more generation resources. And these benefits will have to be approved and somehow quantified to arrive at a final agreement among the countries regarding the allocation of the cost of the transmission project. This is the "first best" approach recommended and applied in the Internal Electricity Market of the European Union. If the countries involved do not reach an agreement, the decision is made by the regional regulator, the Agency for the Cooperation of Energy Regulators, ACER.

A "second best" method

Several "engineering-based" methods have been proposed and some have been implemented. All of them are based on some approach to quantify the "level of utilization" of the considered transmission project by each agent (country, as agreed here). The "level of utilization" can be seen as a proxy for the "amount of benefit" obtained from the project. And the starting point can be the physical flows of energy that can be measured at any given moment exiting the generators, feeding the loads and being associated with each individual line.

The only engineering method that seems to make sense in this context (all others have been tried and discarded, as they can be found to have inconsistent results) – remember that any bilateral transactions must be ignored here – is one tracking the actual flows in each network component upstream and downstream to find its origin and end.[9] This method is called "average participations", and it has been frequently used in transmission costs allocation procedures.

The implementation of this method requires the preparation of a suitable set of representative scenarios of the flow patterns in the regional transmission network. A network representation is needed, either the full one – i.e. with all lines and nodes, either regional or not – or just the regional network, with all the generators and loads being aggregated in the regional network nodes. This representation must be provided by the regional System Operator, with the technical and economic characteristics of each transmission facility, and the estimated injections and withdrawals of power at each node for a number of representative scenarios for the year for which the cost allocation is being performed.

For each generator and each load in each scenario, this method will determine how much it has "used" the capacity of each facility of the regional transmission network, both in its own country and in the other ones. A simple mathematical procedure can be used to bring the data obtained from all the transmission facilities and all the scenarios into a list of numbers per country, indicating how much it has to pay for each individual facility. From this list of numbers, the method can provide a table of figures, with the number in each cell indicating how much country j must pay to country k for the use of all the transmission facilities located in country's k territory.

If some large transmission projects have been exempted, it will be easy to add the results obtained with their individual cost allocation methods to the ones obtained by the method proposed here, making sure that numbers at always aggregated at country level.

Once the cost of the regional transmission network has been allocated to each country, the regulatory authorities know the total transmission revenue requirement for their respective countries for the

[9] We know that this does not correspond to the physical reality of how the electric energy actually moves from one point to another, but it seems the best that we can do. The fundamental problem with the engineering approach is that it can be stated, based on sound physical knowledge, that it is impossible to assign responsibility to any specific agent – generator or load – in the transfer of energy from generators to loads. The transfer is a collective phenomenon where all the generators and loads take part, and it happens guided by the ensemble of transmission lines.

year under consideration. Then the regulators can proceed to apply their internally adopted method to include the transmission component in charges to producers and tariffs to end consumers.

If a large transmission project is exempted from using the general cost allocation procedure, it is recommended that the project developers i) adopt either the "first best" method or the approach described here so that convergence to a single method might be easier; ii) avoid entering in conflict with the three fundamental principles of transmission pricing, as much as possible; remember that, even if the three principles might not be strictly applied (and perhaps in some contexts they should not) they should be always used as a guide or be consulted in case of doubt.

How can a cost allocation method go wrong?

The most obvious wrong approach consists of establishing new transmission charges every time that a bilateral transaction crosses a border, i.e., the bilateral transaction must pay the transmission charge of every country in its path. This is the method known as "pancaking" (easy to understand the analogy for those whose favorite dessert is pancakes). The accumulation of charges can discourage transactions that would have been efficient otherwise.

Any method that is based on charging transmission costs to the commercial bilateral transactions, making use of some engineering calculation of the impact that the transaction has on the network is conceptually wrong and, more importantly, will typically result in transmission charges for cross-border transactions several times higher than they should be, therefore seriously deterring power trade.

A more elaborate method may simply consist of using a load flow calculation method to determine the flows associated with every bilateral transaction in the transmission components of the regional network. This will be repeated for every considered scenario. Then the two agents involved in the transaction will have to pay an annual transmission charge according to the fraction of the network that they have used during the considered year.

These methods are in flagrant contradiction with one of the firmest principles of transmission pricing, which is to ignore commercial transactions when determining transmission charges. The obvious undesirable consequence of these approaches is to overcharge the commercial transactions – therefore disincentivizing regional trade – ignoring that the benefit of the interconnections is more widely shared among the agents (remember: the cost of transmission must be allocated to its beneficiaries). These methods are contrary to what is being tried to achieve, which is to facilitate regional trade.

In addition to discouraging cross-border trade, the accumulation of transmission charges in only those parties that engage in bilateral commercial transactions will make it likely that some entities will oppose the construction of the line, since they will be worse off with it. Trade among countries also benefits other agents beyond those who engage in bilateral cross-border transactions and a correct allocation of the transmission costs must distribute these costs more widely than a method only charging bilateral trade does. With rules that accumulate the costs in a small subset of users, only projects with a cost much lower than their total actual benefit will be acceptable to the majority or even all customers.

5.2. Going further: Locational signals.[10]

We examine now if it is possible to include some locational component in the transmission charges that result from the "second best" approach recommended here. This can be accomplished in two

[10] This section can be ignored if there are already difficulties implementing what has been proposed so far. However, it must be considered that solar and wind power plants can be deployed in a multitude of sites. Locational transmission cost signals can guide towards the deployment of these plants in places where the incurred costs of transmission expansion are minimum or even negative.

stages: with the regional network charges and with the national charges that remunerate the purely national (i.e., not regional) component of the transmission network of each country.

The regional transmission charges computed with the method just described here will charge more to predominantly exporting countries located far from predominantly importing countries, and also to predominantly importing countries located far from predominantly exporting countries, than to countries that do not import or export much. Therefore, the national regulators should charge the regional component mostly to generators in those far and predominantly exporting countries and mostly to demand in those far and predominantly importing countries.

Similar principles apply at national level. A national regulator, with support from the national system operator, can apply a cost allocation method based on "tracking" the actual flows corresponding to representative scenarios of actual or simulated generation and demand. Now, in areas of the country where generation prevails over demand generators should be charged more. Conversely, in areas that import power it is demand that must be charged more. The regulator has to balance the additional complexity of these methods versus the estimated usefulness of sending locational signals. New generators – in particular solar and wind farms –are the best candidates to receive these signals, because they generally have more freedom than new demand to pick a site to deploy the plant. Locational signals are most effective for potential new generators looking for a site or for old generators doubting whether to retire or not. And, as our third fundamental principle tells us, the effectiveness of the signal stems from being known a priori and for a long enough period of time, for instance, the next 10 years.