Engineering, Economics and Regulation of the Electric Power Sector

Spring term 2010

Instructor: Ignacio J. Pérez-Arriaga

Course number: ESD.934, 6.974

TERM PAPERS

Logistics

- Papers can be prepared individually or in teams of 3 people. See below.
- Length: about 25 pages (single space, 12 point) for individual papers and also about 25 pages for each individual contribution to the team papers. But it depends on the topic.
- The two options:
    A. *Default (or common) option:* There will be a default topic, which will consist of answering a set of common questions following a certain storyline in the context of the three electric power systems that have been already selected by the members of the team at the beginning of the course.
    B. *Individual option:* The other option is to develop one topic of your interest within the list that is provided below. More than one person can choose the same topic, but it has to be developed individually. You can also propose a topic outside those contained in the list, although there is no guarantee that it will be accepted. You will have to persuade the instructor of the course.
- There will be a final individual presentation of all topics in some sort of marathon-like session(s) at the end of the course. It will not be mandatory to attend to this session(s) <except when you are presenting your paper, obviously>, although it is highly recommended.
- If in doubt about your knowledge of the subject, the instructor will have the possibility of asking as many questions as he wants (at the time of the presentation of the term paper or at any other convenient time) to make sure you have learned enough to have a good grade.

Suggested topics for the individual option *(a more precise definition and a set of reference documents may be provided to those with an interest in any of these topics)*

1. **Review of RPI-X in the context of distributed generation, demand response and smart grids.** The UK regulatory authority OFGEM is presently carrying out an in-depth review of the RPI-X method, as currently applied to electricity and gas networks. Most documents of this review are available at the OFGEM website. The objective of the term paper is to review this documentation, evaluate the present method and the reasons for a change, examine and describe what is being proposed and make a recommendation for the system of your choice. In particular you will have to examine

the cases of strong presence of distributed generation and demand response, as well as the trend towards "smart grids". Losses and quality of service, as well as innovation incentives have to be included in the picture. Comparisons with other methods or international experiences are welcome.

2. **Transmission regulation for the future US electric grid.** A critical review of electricity transmission regulation in the US at federal, regional (ISO or RTO) and state levels. You have to select one or more ISOs or RTOs of special interest. Examine useful comparisons with European regulation at state and EU levels. You have to cover investment, access and pricing issues. Examine the trade-offs between centralized and decentralized planning approaches. Examine the possibilities of application of some kind of performance-based regulation. Make a proposal about the regulatory changes that would be necessary to have an adequate transmission grid, able to cope with the expected challenges of the US power system during the XXI century.
3. **Generation capacity mechanisms.** There is concern that with a large penetration of intermittent generation, and the pressure to reduce CO2 emissions, the future optimal mix of technologies will be very different from what is now. In particular there may be concern about getting the right amount of investment, especially when a large fraction of the installed capacity is intermittent. Capacity mechanisms could be of help in this respect. Make a critical evaluation of the regulatory instruments that have been adopted and/or implemented in the US (such as capacity payments or capacity markets) and elsewhere to promote adequacy in the investment of generation capacity. Describe and evaluate in detail the Forward Capacity Market in New England (or any other advanced scheme). The potential role of demand response. Same for plug-in hybrid vehicles (PHEVs). Is there a need for specific regulation of demand response and PHEVs? The treatment of interconnectors. Review of and comparison with other meaningful international experiences. Make a detailed and justified recommendation for the system of your interest. Think of how to overcome any problems in the implementation of the method that you propose if the level of horizontal concentration in generation in your power system is high.
4. **Market power mitigation.** Critical review of regulatory approaches and international experiences for the mitigation of market power in wholesale electricity markets. Metrics and quantitative models. In-depth review of the case of the Single Electricity market of Ireland (since there is abundant documentation and several methods have been carefully considered) or any other out of the many relevant ones. Evaluation of the regulatory mechanisms that have been proposed and implemented. Recommendations for the power system of your choice.
5. **Wholesale market design: auctions.** An analysis of auction mechanisms in wholesale electricity markets. Complex bids versus simple bids in day-ahead markets. Trade-offs of efficiency vs. transparency vs. market power mitigation. Approaches to the determination of energy market prices. The search for the "optimal" mechanism of formation of energy prices. Different approaches to market clearing in the short-term. Acceptable and less acceptable bidding strategies, in particular regarding the recuperation of investment costs and start-up costs. The potential for exercise of market power. The convenience of a Bidding Code of Practice.
6. **Wholesale market design: ancillary services.** Review of international experiences in the treatment of ancillary services in wholesale electricity markets with either market oriented mechanisms or other regulatory instruments. Examine the adequacy of the current schemes in the presence of a strong penetration of intermittent generation sources, as well as demand response. Make a detailed critical review of an interesting

existing approach and also a proposal of a regulatory scheme for ancillary services in the power system of your choice.

7. **Renewable generation.** A critical evaluation of regulatory instruments for promotion of renewable energy sources in electricity generation. International experiences of successes and failures. Special attention should be paid to the necessary adaptation of the wholesale market rules, the implications for financiability of the investments of any specific support regime and the impact on the dispatch and market remuneration of other technologies. Provide an in-depth analysis and give your opinion on the debate regarding "the costs incurred by wind and/or solar penetration". Regulatory recommendations for the power system of your choice.
8. **Universal electricity access.** Adequate regulatory approaches to promote universal electricity access in countries where this has not been achieved yet. Review of past successful and less successful experiences. Lessons learned. Elements for a comprehensive approach to rural electrification. Proposal of an approach that is well suited to some country of your interest (which will be different from the power system of your choice during the course). Do you consider that intensifying and/or refining the process of restructuring and liberalization of the power sector in this country would have a positive, negative or neutral factor to facilitate universal access to electricity in the hypothetical (or actual) situation that has been described? Justify your answer. You have to outline the strategy that you would follow to provide universal access to electricity to all the citizens in this power system in a reasonable amount of time (this may vary with the specific power system, but let's say that in no more than 10 years).
9. **Mathematical modelling of an optimal generation mix subject to constraints**. The objective is to examine the future optimal mix of technologies for electricity production in the long-term (e.g. 2030 or longer). The expected presence of a large deployment of renewable generation sources, either because they become competitive or because they are mandated to enter as part of a higher level energy strategy, as well as the anticipated prices of CO2 will have a strong influence in the long-term optimal mix of generation in any given power system. The objective here is to write a computer model that is able to reproduce the major trade-offs among the different technologies and the costs and implications of some regulatory instruments and targets. This topic is less regulatory and more suitable for mathematically oriented students, with a good knowledge of optimization and programming. However, good regulatory insights can be obtained from a working model like this.
10. **Distribution and retail in the presence of a strategy of energy savings and conservation.** Examine the compatibility of existing schemes of regulation of the distribution and retail activity and the promotion of energy efficiency and conservation. Evaluate the convenience of establishing real-time pricing, unbundling of the metering activity from distribution and retailing, default tariffs, specific mechanisms such as the white certificates or the decoupling of demand growth from energy conservation measures, and other regulatory instruments. Examine the impact of having the distribution and retail functions being performed by the same company.
11. **Electricity contracts**. The role of electricity derivatives in wholesale markets and the allocation of risk. A critical review of the hedging instruments currently in use. Relationship with market power mitigation measures. A recommended approach for market power mitigation in a power system of your choice. Transmission related hedging instruments. Taxonomy of these contracts and critical evaluation of the different approaches. Implications for market power mitigation. In-depth analysis of the current approaches to the establishment of firm transmission contracts.

12. **Markets versus Governments.** The role of markets vs. governments in the regulation of the energy sector, and the electricity power sector in particular. Analysis of the current situation, with a trend towards liberalizing the energy markets while at the same time feeling the need to impose diverse types of sustainability objectives. Review of opinions on this subject and discussion of different international approaches. The cases of the EU and the US, among others. The role of indicative energy (and electricity) planning. Actual degrees of freedom left in practice to electricity markets. Relevance for the future of energy (and electricity) regulation. Making energy policies and energy markets compatible.
13. **Locational signals for new generation entries**. Large volumes of generation investments will be needed in the next decades. It is anticipated that a large fraction of this generation might depend on local resources (such as wind, solar or facilities for CO2 storage) and will have to be placed far from the major load centres. This may create some stress on the transmission network, with environmental and economic consequences. It will be then necessary to send the right economic and regulatory signals to prospective new investors about the implications of their choice of siting. The objective is to identify all plausible locational signals that can be used with this purpose (transmission charges, nodal energy prices, marginal sensitivities of CO2 emissions to demand growth, etc.). Find a justification for their use. Propose a design for each one of these signals in the context of the system of your interest. Recent SEMC documents provide a good case study.
14. **The Discovery project in the UK**. This is a recent critical review of the entire liberalization model for the electric power system in the UK, which questions basic features of the existing approach. The objective is to examine the project report, as well as other associated documents and the UK model itself, and provide a personal opinion and recommendation on this subject.

The common (team) option

Most of the questions that will have to be answered in the term paper refer to a common storyline. You have to assume that in the specific power system of your choice a very large penetration of intermittent generation (wind, both on-shore and, if possible also off-shore; also different kinds of solar), of the order of 40% or more of the total demand of the power system, is expected to occur during the next 20 years. Then you will have to identify and to evaluate the different regulatory changes that will be needed to cope with this new situation.

You may choose to answer all the following questions by yourself. Alternatively, you may work in a team of three people to answer the questions. The members of each team will be selected by the instructor of the course, attending to the diversity of backgrounds and the chosen power systems of interest of the participants in the course that have opted for this option. Now the answer to each question will have to be applied to each one of the three power systems of the members of the team, and the recommendations may vary for each system, depending of the specific circumstances. Each member of a team will be responsible for writing a third of the questions, but will have to know about the answers to all of them. This means that each member of the team has to get familiar with the three power systems that have been chosen by the members of each team and discuss with the other members of the team about all the questions.

It follows the list of the questions to be answered. Some of them are similar to the ones for the individualized term papers. The difference is that here you just have to show a good

understanding of the issues that have been covered in class, plus what is contained in the course reading material. In the individualized term papers the student is supposed to explore additional documents, examine the issues in more depth and to make a more personal contribution to the topic.

1. **Energy legislation**.

   You are supposed to know by now the process of restructuring and/or liberalization that has taken place in each one of the three systems to be considered and to have an opinion about its performance. Topics on which you should have an opinion include: whether the process of restructuring and/or liberalization has been correctly designed and executed, unbundling of activities and resulting system structure, wholesale and retail market rules, potential for the abuse of market power, remuneration of the regulated activities and incentives for efficiency improvements, treatment of environmental / sustainability objectives and constraints, electricity prices, quality of service, security of supply, transmission investment or governance of the relevant regulatory institutions.

   You should be also familiar with the current body of legislation governing the power sector. Indicate what type of changes, and at what level, will be needed to reform the current legislation of the power system of your choice in order to achieve about 40% of penetration of renewable electricity generation by 2030.

2. **Markets versus Governments.** Do you think that it would be justified in the power system that you are considering to establish such an ambitious target for the contribution of renewables to the production of electricity? On which grounds could a mandatory target like this be established? Express your ideas about the role of markets vs. governments in the regulation of the energy sector, and the electricity power sector in particular. Consideration of shorter-term goals (affordable prices, competitiveness, immediate security of supply) and longer-term objectives (the different dimensions of sustainability). Actual degrees of freedom that should be left in practice to electricity markets. Make the arguments specific for the power system of your choice. Discuss the role (if any) that indicative energy (and electricity) planning could play in this respect.

3. **Renewable generation.** Now you have to choose the most adequate regulatory instrument to achieve this type of target in renewables penetration in the considered power system. What regulatory approach would you suggest to meet the prescribed target with a maximum confidence and the lowest cost? Describe and justify your choice. Describe the discarded choices and the reasons why you have not chosen them. Pay also attention to the necessary adaptation of the wholesale market rules, the implications for financiability of the investments of any specific support regime and the impact on the dispatch and market remuneration of other technologies. Who should pay for any extra costs associated to the mechanisms of promotion of renewables?

4. **Distribution.** Assume that the RPI-X method is used for price control of the distribution network in your system. Indicate what difficulties may appear in the application of this method if a significant fraction of the new renewable generation will be connected at distribution level. Explain how the RPI-X method could be upgraded. Presently the UK regulatory authority OFGEM is carrying out an in-depth review of the RPI-X method, as currently applied to electricity and gas networks. Most documents of this review are available at the OFGEM website. It could be useful to examine the documentation of this project. Make a recommendation for the system of your choice. Losses and quality of service, as well as innovation incentives have to be included in the picture.

5. **Transmission.** Intermittent renewable generation may be far away from the demand

centres in the system of your choice. This may require major reinforcements and perhaps a major reconfiguration of the transmission network. Check if the existing regulation in your power system is adequate for this new situation. Examine available international experiences. You have to cover investment, access and pricing issues. Examine the trade-offs between centralized and decentralized planning approaches. Examine the possibilities of application of some kind of performance-based regulation. Make a proposal about the regulatory changes that would be necessary to implement in your system.

6. **Locational signals for new generation entries**. This applies to future renewable generators that could be located either in transmission or distribution networks. For both types of networks, discuss the convenience of using appropriate economic and regulatory signals for prospective new investors about the implications of their choice of siting. Be specific about the locational signals that you would use (if any) in your considered power system.

7. **Generation adequacy.** There is concern that with a large penetration of intermittent generation, and the pressure to reduce CO2 emissions, the future optimal mix of technologies will be very different from what is now. In particular there may be concern about getting the right amount of investment, especially when a large fraction of the installed capacity is intermittent. Capacity mechanisms could be of help in this respect. Review the best schemes that have been proposed or applied elsewhere. See how they could be adapted to the case of large penetration of intermittent generation. Make a detailed and justified recommendation for the system of your interest. Examine the potential role that demand response could play here.

8. **Market power mitigation.** Do you consider that the present level of horizontal concentration in your power system is compatible with the existence of a working electricity wholesale market? Do you consider that there is any other major barrier that should be removed if you want a wholesale market to function correctly (or to create one, whatever is the case? Consider now that 50% of the new intermittent generation capacity will add to the capacity of the largest generation company in your country of interest, with the rest being evenly distributed to the remaining generation companies. Does this new situation increase the potential for the exercise of market power in your power system? Indicate (in priority order: first those measures that you would recommend first) the regulatory measures that you would advise to adopt, if any. Justify your answer. You can refer to existing regulatory approaches and international experiences for the mitigation of market power in wholesale electricity markets. Mention the regulatory mechanisms that have been proposed and implemented.

9. **Wholesale market design.** Examine the rules of the wholesale market in the power system you are considering and assess their suitability in the context of the anticipated strong presence of intermittent generation. Indicate the changes that should be made to establish a level playing field for all the different technologies. In particular the following topics will have to be contemplated: a) rules of the day-ahead market, congestion management, intra-day markets, and any markets for operation reserves or balancing markets; b) organized or over-the-counter markets for contracts; c) the formation of the electricity market prices; d) capacity mechanisms for adequacy and firmness. Special attention will have to be placed on the level and characteristics of operation reserves, because of the strong presence of intermittent generation in the power system. Analyze any special needs for operating reserves that may result from the large component of wind and solar generation in the power system, as well as the potential role that demand response may play here. Should intermittent generation be charged for the requirements that they might impose on the utilization of operating

reserves?

10. **Retail market design.** In parallel with the deployment of renewable generation, the best immediately available approach to reduce CO2 emissions in a well developed economy is the application of measures of energy efficiency and savings. In the electrical power sector this could be achieved by letting the consumers experience the hourly electricity prices so they would try to avoid consuming at times when prices are highest. However, present electricity prices are typically too low for bringing a strong consumers' response, in particular for the residential sector. If the regulator, because of sustainability-based constraints, wants to increase the consumers' response in order to reduce demand in the system, what kind of regulatory instruments do you think should be used? Make sure that the instruments that you propose apply the right incentives on the right agents. What could be the role of retailers and/or distributors and/or energy service companies in this task? Justify your choices, in particular regarding the role and the incentives for each kind of company in the context of the power system that you are considering.
11. **Universal electricity access.** The level of electrification (percentage of people with access to electricity) is low in many countries. Almost one third of mankind does not have access to modern forms of energy. Do you consider that restructuring and liberalization of the power sector in these countries can be a positive /negative or neutral factor to facilitate access to electricity in these countries? Which measures do you consider are necessary to achieve the objective of universal access to electricity? Would you consider including any consideration about climate change when addressing this issue? Could renewables play a role here? Should these countries consider also any mandatory targets for penetration of renewable energy sources for electricity production? Do you suggest any other means for promotion of renewables in developing countries that makes any sense?
12. **CO2 markets and prices.** Assume that the power system that you are considering is part of an emission trading scheme of the cap-and-trade type (such as in the EU or in the US Northeastern region under the Regional Greenhouse Gas Initiative, RGGI). Then you should answer the following questions:

    - Do you think that the market price of electricity should internalize the price of the CO2 emission allowances?
    - If the electricity market price increases because of the influence of the price of CO2 emissions, do you think that it is adequate that power plants that do not have CO2 emissions (such as renewables, hydro or nuclear) should have their revenues also increased?
    - Presently in the EU the power plants with CO2 emissions are given for free an amount of emission allowances that more or less compensates the amount that they would have to buy in order to have emissions in the future that are similar to the emissions that they had in the past. This has been also contemplated (partly, at least) in some of the bills that have been proposed in the US. Is this regulation correct?
    - If a volume of emissions is given for free to each power plant, as indicated in the preceding bullet, do you think that this has an impact on the merit order in the dispatch of the different generation technologies in the electricity market?
    - In the present EU regulatory scheme for emission trading, an old or inefficient generation plant will stop receiving emission rights at the time the plant retires

from the market and decides to stop activities for ever. Is this a correct regulation? Justify your answer.

ESD.934 / 6.695 / 15.032J / ESD.162 / 6.974 Engineering, Economics and Regulation of the Electric Power Sector

Spring 2010