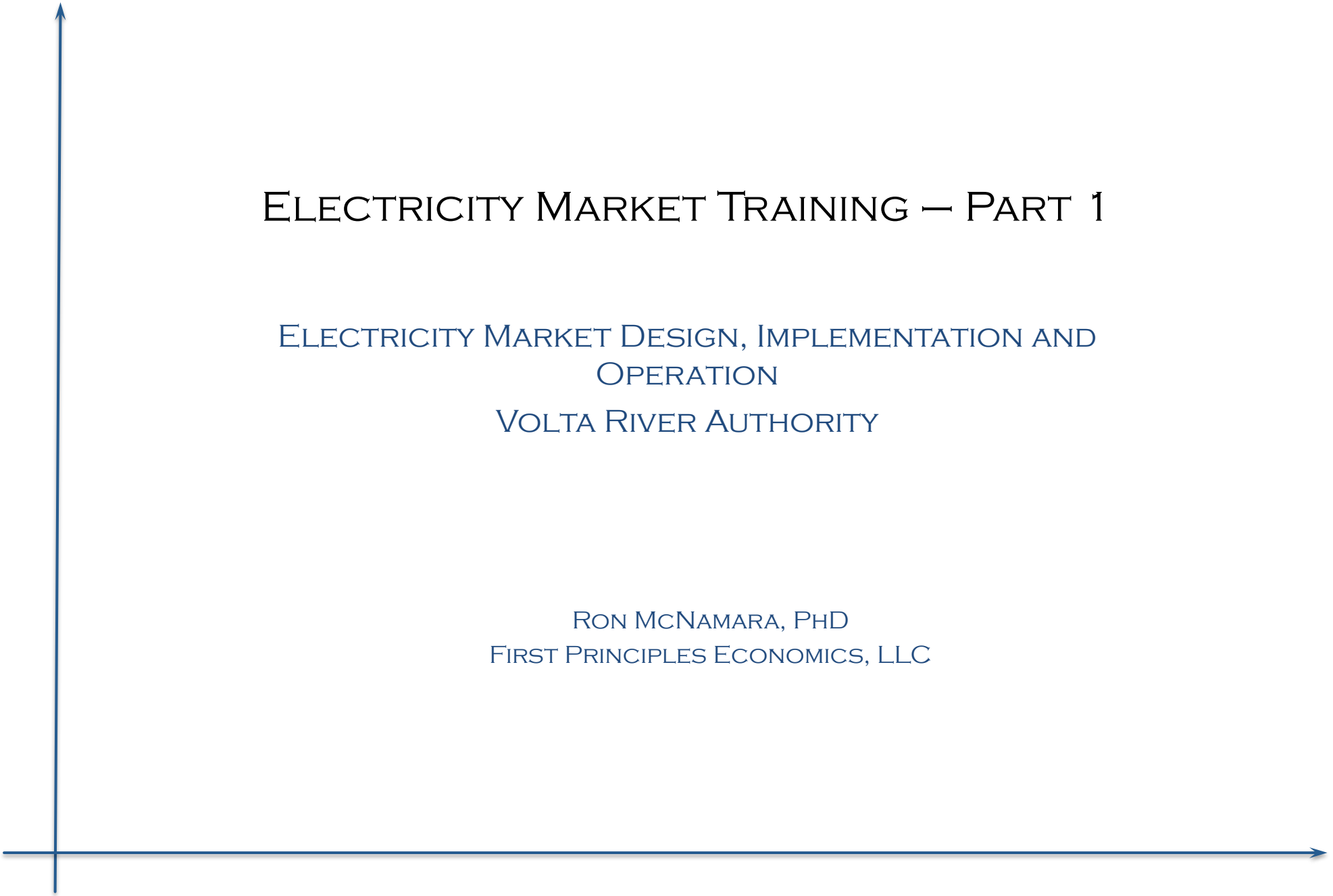
Electricity Market Training – Part 1

Electricity Market Design, Implementation and Operation

Volta River Authority

Ron McNamara, PhD
First Principles Economics, LLC



Part 1 – Outline

Part 1 focuses on 4 topics:

I. Context for reform in the electricity industry
   A. Why are we here?
   B. Non-discriminatory open access to the transmission system.

II. The importance of the underlying technology.

III. Dispelling three common myths about electricity and transmission.
   A. Myth #1 – The capacity of the transmission system can be pre-determined accurately enough to allow real time operation of the grid.
   B. Myth # 2 – Energy and reliability can be separated.
   C. Myth # 3 – Forward markets can "solve" real time transmission constraints.

IV. Why the coordination function (i.e. dispatch) is the key.

Context for Reform in the Electricity Industry

Why are we here?

I. THIS IS IMPORTANT!

A. In almost every market design process, the reason behind why the process was started is either never learned or forgotten along the way…and somebody ends up paying for this.

1. The rationale for reform varies: government fiscal constraints, physical shortages, need for foreign capital, etc.

B. Markets that have been "redesigned."

1. Virtually every market in North America as well as the UK market has undergone fundamental change since it began operation.
2. While there have been changes some markets have not had to undergo fundamental revision.
3. Tremendous implication for the commercial conditions of the participants, particularly the generators.

II. Unique combination of technology and financial imperatives.

New Zealand Example – Part 1

New Zealand provides a useful example:

I. Market began on 1 Oct 1996 following a very long process.
   A. Initially the electricity industry was part of the Government – New Zealand Electricity Department (NZED) – producing and transporting electricity to local government-owned distribution/retail companies.
      1. Monopoly wholesale/transmission selling to monopoly local wires and retail companies.
   B. At the macroeconomic level, New Zealand was getting deeper and deeper in debt, until in the 80's it was effectively unable to borrow. Change was forced upon it by international capital markets.
   C. The debt in the electricity sector which had been used by the govt. to foster economic growth and job creation was a huge drain on the government's budget.
      1. This was the impetus for reform.
   D. Period of foot dragging...consultants, reports, analysis, etc.
   E. In the early 90's hydro shortage caused blackouts. Government investigation highlighted that there were no prices to signal shortage conditions which starts the reform process.

New Zealand Example – Part 2

II. Reform process "heats up"...high voltage transmission activities are separated from generation.

A. Generation is put into a "State Owned Enterprise" (SOE)

I. Electricity Corporation of New Zealand (ECNZ). Profit maximizing objective with the Treasury as the single shareholder.

II. Transmission is put into "Transpower."

B. Distribution/retailers are privatised. Shares are given to the residents of the local monopolies.

I. In this sense New Zealand, de-regulated the retail sector first.

C. Government would like to privatise their generation assets but doesn't have the votes in parliament. Instead it gets management of ECNZ to voluntarily split itself into two companies.

D. Two companies requires some way mechanism/methodlogy to sell/buy the "overs" and "unders" (i.e. the differences from the bilateral contract amounts) from planned output, i.e. a market is required.

Other Situations

World-wide initiative.

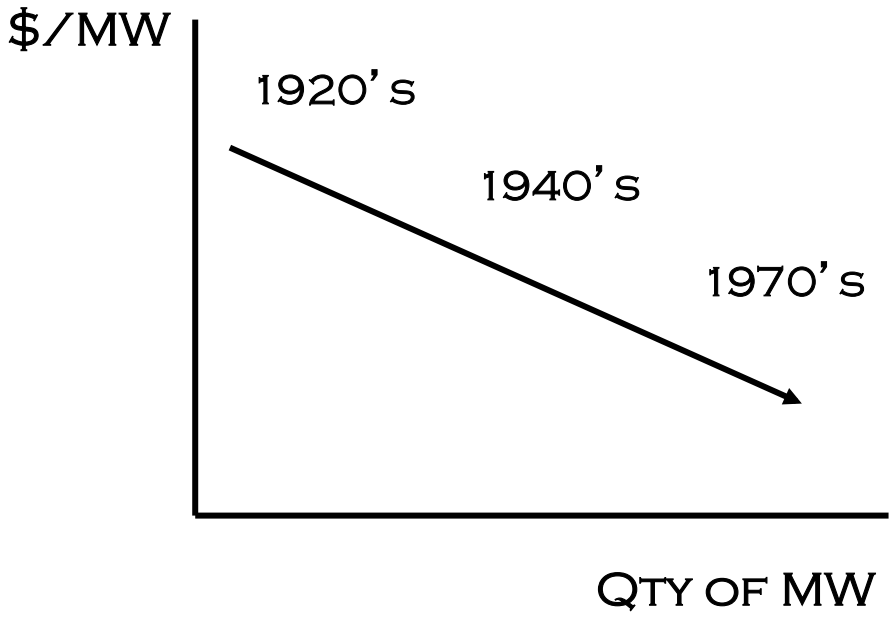
I. Elsewhere around the world there are (to a greater or lesser extent) reform has resulted in organized markets in Australia, Western Australia, Singapore, New Zealand, the Philippines, Scandinavia (Nord Pool), Great Britain, Ireland, the Netherlands, Spain, Portugal, Turkey, Italy, the Czech Republic, Brazil, and Chile (and a few others).

   A. Many different underlying reasons:

      1. Australia – microeconomic reform, financial situation in the State of Victoria.
      2. UK – microeconomic reform, budgetary situation.
      3. US – overvalued assets, changes and increased use of natural gas.
      4. Ghana...???

Underlying Technology Drove Institutional Structures…

I. Efficiency from size in generation:
   A. Cheaper per unit cost the larger the generation unit.
   B. Leads to the development of large plants.
II. Benefits from internalizing the size vs. location decision (i.e. vertical integration).
III. Impetus for regulation.

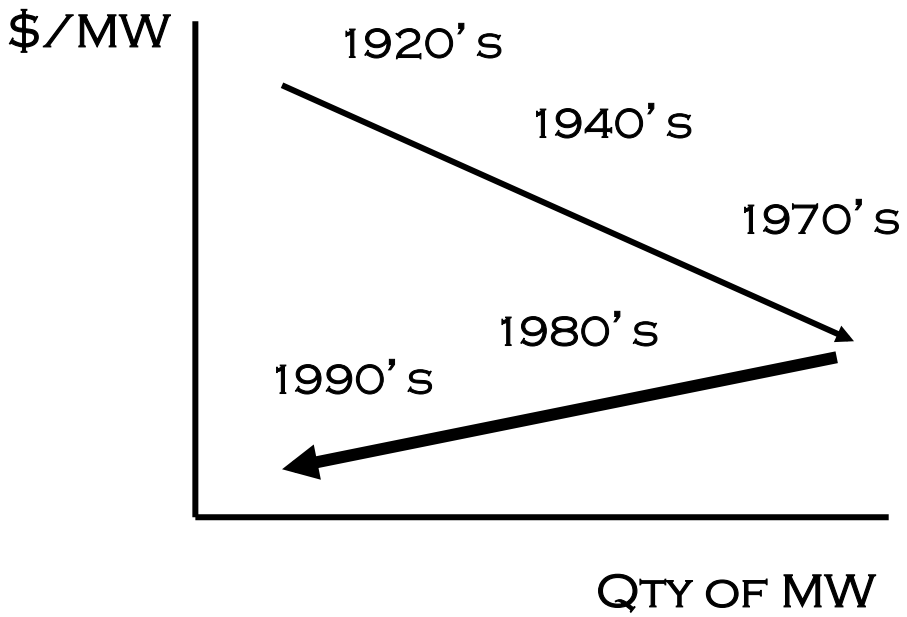


...But When The Technology Changes...

I. Efficiency gains in small scale generation.
   A. Advances in technology arising from the space program.
   B. Small plants can now compete effectively with large scale generation.
   C. Trend of declining long run average cost of generation has been reversed.

II. Eliminates reason for regulating generation.
   A. Puts increased focus on location decision.
   B. Must separate electricity as a commodity from transmission as a service.

III. Forces change on the entire sector:
   A. In particular the need for competitive generators to have non-discriminatory open access to the transmission grid.



What needs to happen?

With a competitive generation sector there is a need to have non-discriminatory open access (L.I. 1934 specifically states *"the rules shall ensure that the transmission system provides a fair, transparent, non discriminatory, open access…transmission and delivery of electricity"*)…

I. The question then is how should non discriminatory open access be implemented?

II. Unbiased open access to the system means that no individual generator or specific type of generation technology receives preferential treatment.

III. Why has implementation of non-discriminatory open access been linked to the creation of a real time spot market for electricity?

Underlying Structure

I. There are three "cornerstones" to the process of change that is going on in the electricity industry in Ghana:
   A. The nature of electricity itself.
      1. Electrical energy cannot be stored.
         – Within a tight band supply and demand must be equal at all times.
      2. Network production.
         – Network externalities exist.
   B. The regulatory and legislative institutional infrastructure.
      1. Electricity as a monopoly good.
      2. Defined as an "essential" service.
   C. The nature and future of ownership in the industry.
      1. Ownership affects business objectives and hence investment.
II. Early days in the process...

Establishing a Starting Point by Dispelling Some Popular Myths

I. Myth #1: Transmission capacity can be determined beforehand.
   A. In the US, the first attempt at establishing non-discriminatory open access was based on the (incorrect) assumption that transmission capacity could be (1) predetermined and (2) allocated efficiently enough that there was no need for centralized coordination of the transmission system.
      1. Leads to concepts such as Total Transfer Capability (TTC), Available Transfer Capability and the Open Access Same Time Information System (OASIS).
      2. Policy makers tried to impose the structure of the natural gas market on the electricity market.

II. Myth #2: Energy and reliability can be separated.
   A. Keep the market operator out of the "the market"…separate the physics from the economics.

III. Myth #3: Forward markets can "solve" real time transmission constraints.
   A. Pre- determined and allocated transmission capacity (i.e. physical transmission rights) can be exchanged to ensure reliability.

Start With The Laws Of Physics

I. It may seem obvious, but it is useful to remember that electricity flows are always and everywhere subservient to the laws of physics.
   A. Not regulations, legislation, contracts, prices, etc.
   B. In particular, electricity is governed by Kirchoff's and Ohm's laws.

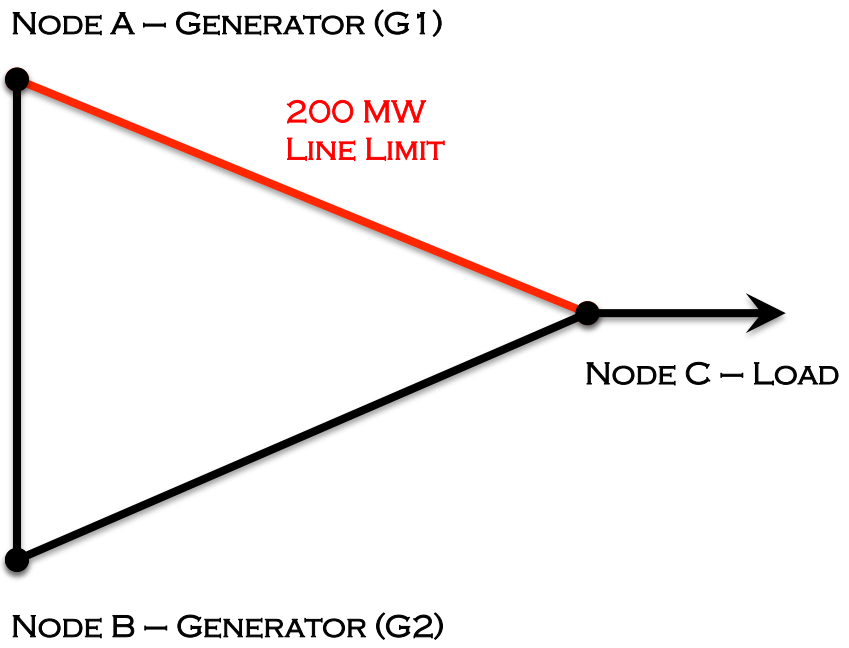
II. The primary question of electricity market design is how to align the the "market" with the physics.
   A. By align we mean ***MAKE CONSISTENT***, i.e. the market design, operation and outcomes should be consistent with the physics of electricity.
   B. Obviously the laws of physics hold precedence and the market must be based on the physical reality.
   C. Whenever this overarching objective has been ignored the market has failed.

III. Cannot be stressed too much....**THE MARKET MUST BE BUILT FROM THE FUNDAMENTAL ELEMENTS OF ELECTRICITY.**
   A. Not from government policy, economics, legal institutions, etc.

Myth #1 – Determining Transmission Capacity

I. Start with a simple network model:
   A. 3 interconnected nodes.
   B. 1 transmission line with a thermal constraint of 200 MW (line AC).
   C. 2 generators (G1 and G2) at Nodes A and B respectively.
   D. 1 load at Node c.
   E. Lines are equal length and lossless.

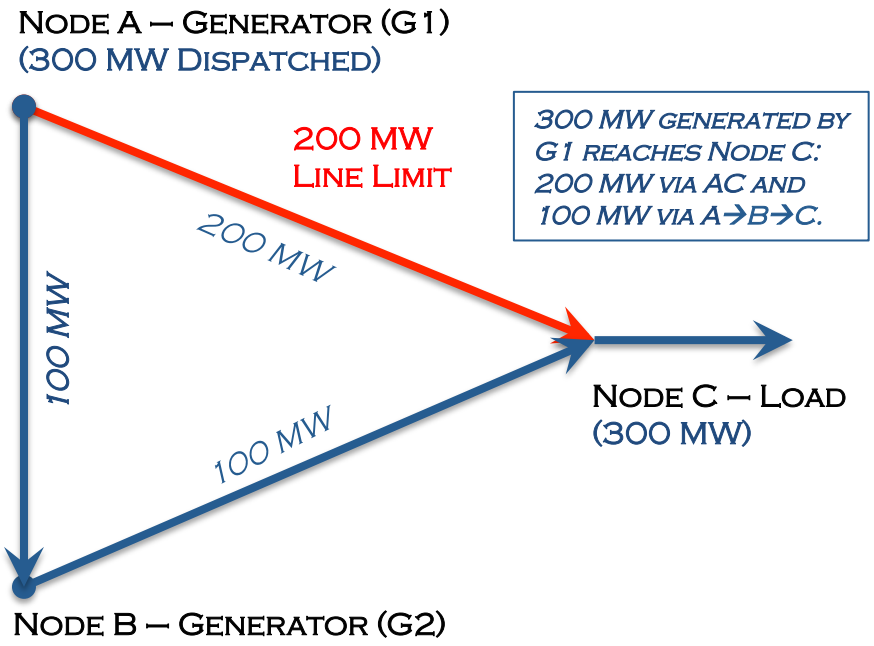
II. This 3-node model will used throughout the training.
   A. Given the assumption of equal length, 2/3 or every MW generated by G1(G2) will flow along AC (BC) and 1/3 will flow along AB (BA) and BC (AC).



Suppose Load Is 300 MW – Use G1

I. If, load at Node C is 300 MW:
   A. It is possible for G1 to meet all the load.
   B. But if G1 does produce 300 MW then G2 cannot produce anything.

II. If, G1 produces 300 MW then the total capacity of the transmission system is 300 MW.
   A. Neither G1 or G2 can produce more output without increasing the flow on AC which will violate the line limit.
   B. Does this mean the capacity is 300 MW? *NO!*

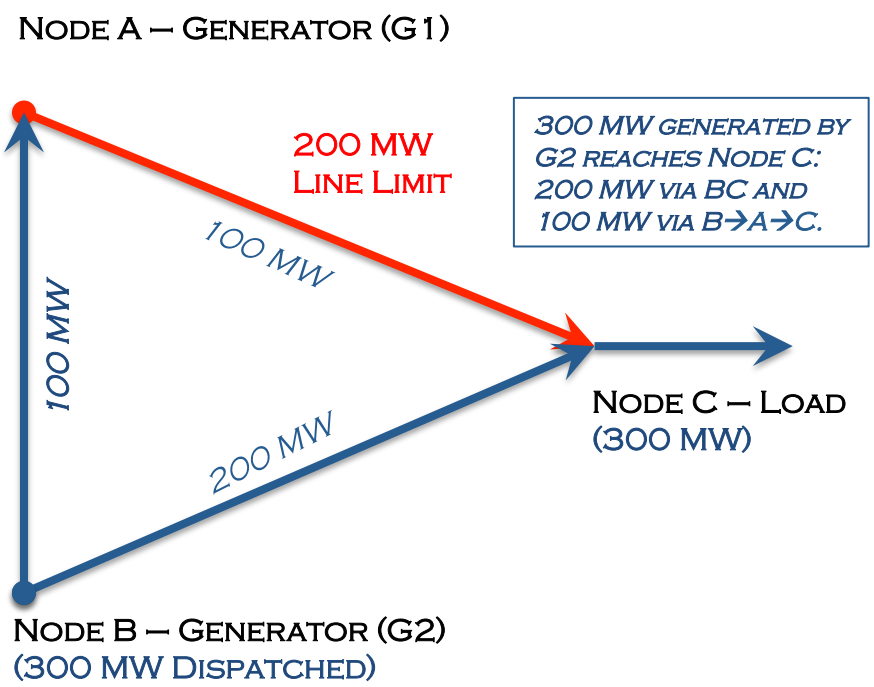


Suppose Load is 300 MW – Use G2

I. If, load at Node C is 300 MW:
   A. It is also possible for G2 to meet all the load.
   B. If G2 produces 300 MW then G1 can still produce, i.e. the line limit on AC has not been reached.

II. If, G2 produces 300MW then the total capacity of the transmission system is ***more*** than 300 MW.

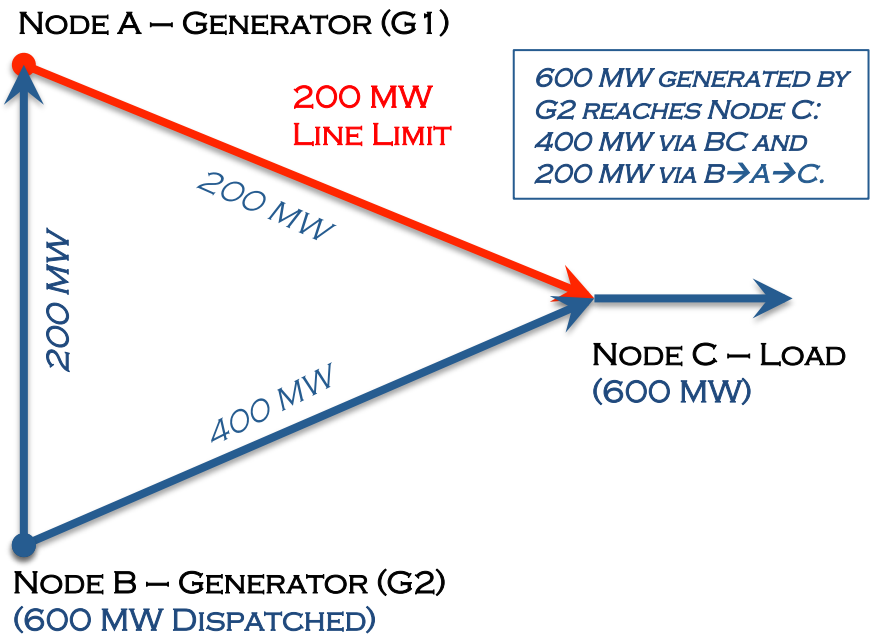
III. This example highlights the central issue of non-discriminatory open access… who makes the decisions about which generation runs… and on what basis?



Now Suppose Load Is 600 MW

I. IF, load at Node C is 600 MW:
   A. It is not possible for G1 to produce 600 MWs. If they did 400 MW would flow along AC.
   B. The only possible solution is for G2 to produce all 600 MWs.
   C. The maximum capacity of this transmission system is 600 MW.

II. How much physical capacity should be defined?
   A. 300 MW, 600 MW…or somewhere in between?



What is the real problem?

In order to have true non-discriminatory open access every generator must have an equal opportunity to sell their power…
and the system must be operated reliably!

I. Using the results from the previous examples, suppose we issue 300 MWs of physical transmission capacity rights. In order for a generator to run, they must use transmission rights to schedule from their generation facility (source) to the load (sink).
   A. Now assume that for whatever reason, G1 ends up with all the rights.
   B. On any given day, G1 uses their physical transmission rights to schedule power from their plant at Node A to load at Node C.
   C. As Long as the load is ≤ 300 MW everything is fine. But what happens if load is more than 300 MW?
      1. With only 300 MW of physical transmission rights available, no additional generation can be scheduled…nobody would have the "right" to schedule.
      2. If the dispatcher forced somebody to generate…they would simultaneously violate G1's rights. As was shown, if G1 produces 300 MW, there is no way for G2 to produce anything. The only thing the dispatcher can do in this situation is to mandate that G1 reduce their output and allow G2 to produce, and this would violate G1's transmission rights.

Myth #1: Ability To Pre-define The Capacity Of The Transmission System Is "Difficult"

I. Why is the understanding of this issue important?
   A. Many market design processes assume that the "market" can be largely separated from the details of electricity…"keep it simple"…"we don't need all that complexity."
   B. This assumption requires that the amount of transmission capacity be determined in advance and then "physical rights" can be established for the capacity.
   C. These "rights" are then sold or allocated to market participants.
   D. In order to produce/consume physical power, you must have the "right" to transport it from the source to the sink.

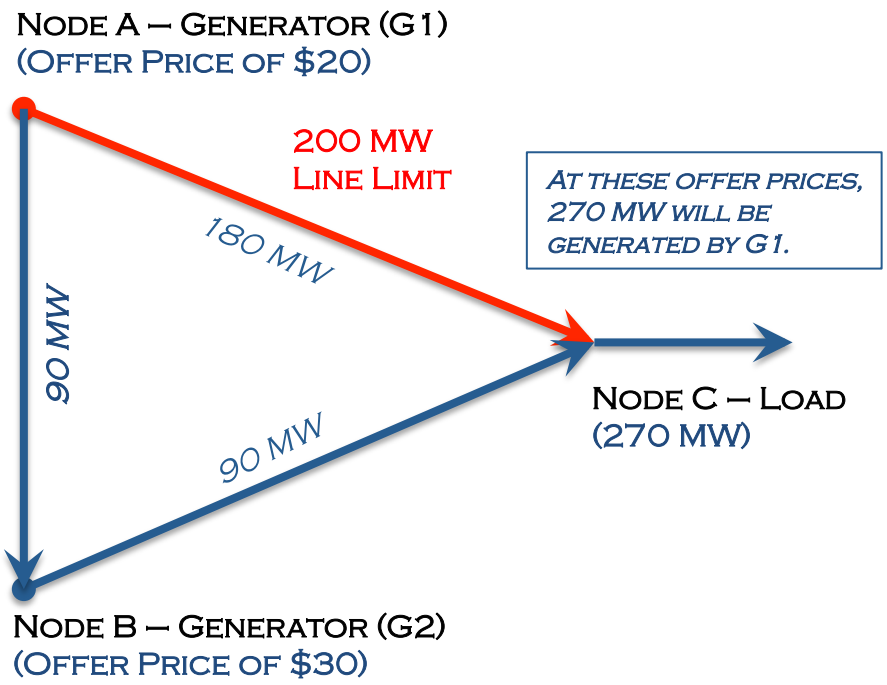
II. The previous examples illustrate the difficulty in pre-defining physical property rights on an interconnected grid.
   A. Neither generator can have physical capacity rights over line AC without knowledge of what the other is doing – as well as the level of load – who makes the decisions?
   B. Note: In the USA, FERC Order 888 tried to ignore these issues and implement the basic structure of the natural gas market in electricity…in the end, it was a costly and failed experiment.

Myth #2 – Electricity Can Be Disaggregated

I. It is common for market design processes to falsely separate electricity from constraint management and/or reliability:
   A. Disaggregate electricity into that used for, say, lighting and that used to keep frequency at 50Hz.

II. Let's use a typical transmission constraint to show why this is not possible.
   A. Congestion is one type of a transmission constraint. It occurs when the limit of a transmission line has been reached.

III. Redispatch example:
   A. If load at C is 270 MW and the offer prices are $20 and $30 for G1 and G2 respectively, then the entire load should be served by G1.

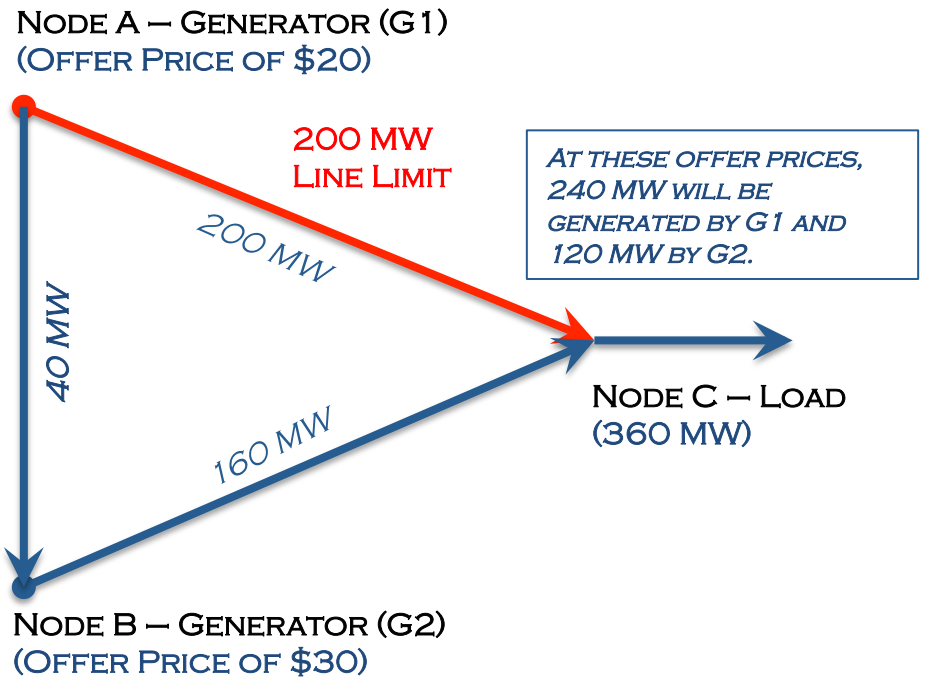


Myth #2 – Separating "Electricity" From Reliability

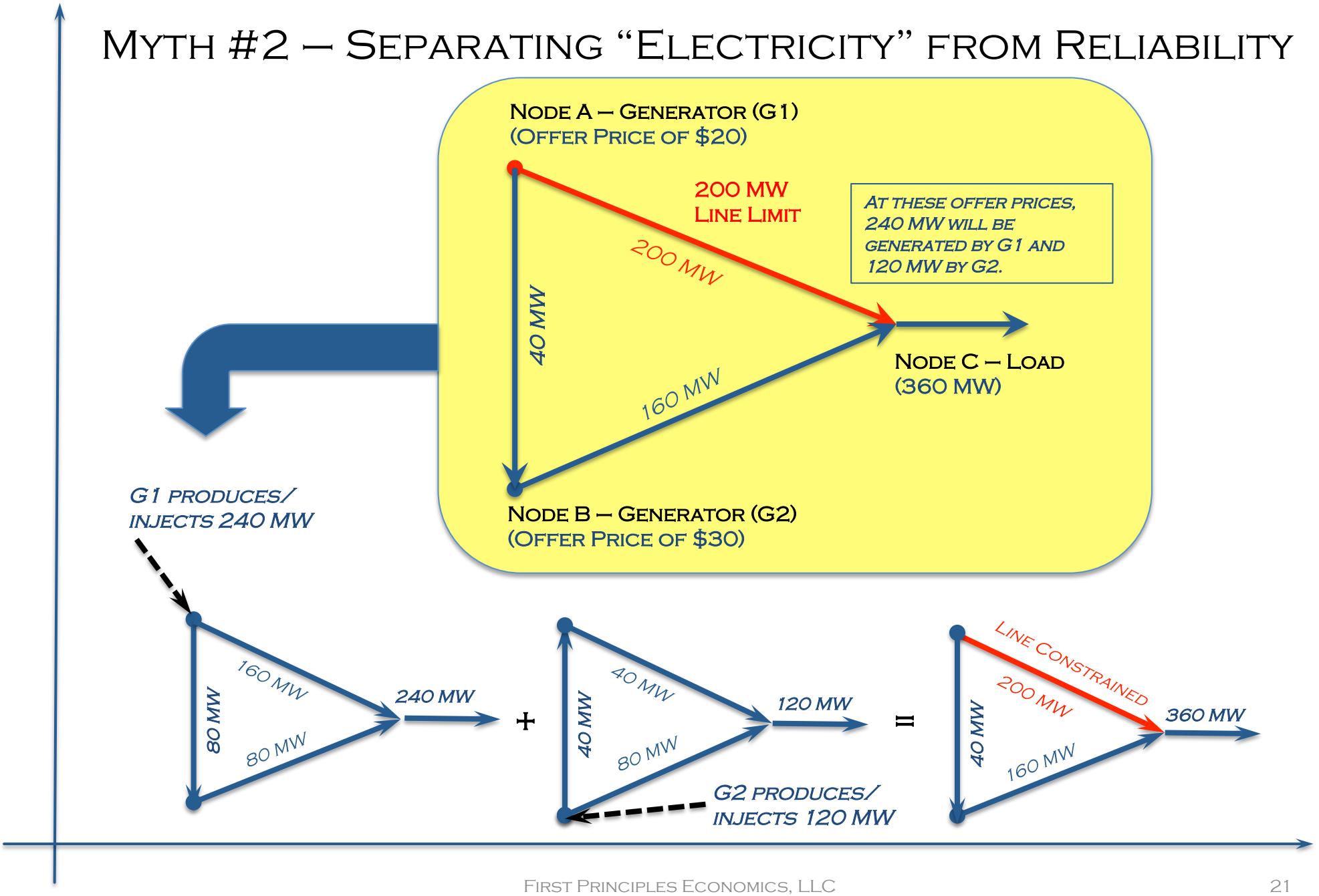
I. Suppose that load is 360 MW rather than 270 MW, then:
   A. Efficient (i.e. least cost) dispatch requires that G1 produce 240 MW and G2 produce 120 MW.

II. May seem counterintuitive…why not produce 300 MW from G1 (the lowest cost generator) and 60 MW from G2 (the high cost generator)?
   A. Because once G1 produces 300 MW, line AC is constrained.

III. Efficient (i.e. least cost) dispatch requires G1 to produce 240 MW and G2 to produce 120 MW.
   A. What physically happens is shown on the next slide.



Myth #2 – Separating "Electricity" from Reliability



Myth #2: Ability To Separate Electricity From Constraint Management And Reliability Is Impossible

I. Why is this important?
   A. In an attempt to create a "simple market", it is often argued that electricity, ***as a commodity***, can and should be separated from other components (e.g., regulation, voltage support, etc.). ***The "market" can then price and allocate the commodity and the dispatcher can provide the other components which are assumed to be insignificant and separable from electricity.***
   B. But the distinction between electricity and reliability is a false dichotomy.

II. The previous example with congestion shows that dispatch must take into consideration both the amount of electricity demanded as well as the reliable operation of the grid.

III. In real time all electrical energy is indistinguishable, i.e. there is no difference between energy used to solve a congestion constraint (or any other transmission constraint) from that used to meet load.
   A. To the extent that there is differentiation it stems from accounting and not from actual physical operation.

IV. All energy in a network is a single integrated physical pool and it must be managed accordingly.
   A. This is an absolutely fundamental concept with respect to market design.

Myth #3: Forward Markets Can "Solve" Real Time Transmission Constraints

I. Assuming that it is possible to determine transmission capacity in advance of when the power flows (i.e. Myth #1) and that electricity can be disaggregated from the management of constraints and reliability (i.e. Myth #2) it follows that once capacity has been determined/allocated and that electricity has been disaggregated then the" market" can allocate transmission capacity in real time.

   A. Not only are both of the necessary assumptions false (i.e. Myth's # 1 & # 2) but it is also incorrect to assume the "market" can operate (i.e. reach equilibrium) in the time frames necessary for real time balancing.

   B. Real time power flows need to balanced at virtually every instant in time and there is no way the "market" can reach equilibrium, i.e. supply = demand, instantaneously.

Implications

I. Every market that has failed to understand why these three ideas/beliefs are myths has failed.

   A. Why? Because each of the three ideas attempts to separate economics (i.e. the market) from the physical laws that govern electricity.

   B. This separation cannot be maintained and it requires some "out of market" solution(s), i.e. the market, because the design is based on fallacies, cannot allocate transmission(and generation either cost effectively, reliably or (most often) both.

   C. This leads to any combination of the following:

      1. Artificially low and/or high prices,
      2. Artificially low and/or high price volatility,
      3. Artificially high "uplift" costs, i.e. costs that are not recovered through the market but rather through an "uplift" charge on market participants,
      4. Unpredictable operations,
      5. Unreliable operations,
      6. Costly redesign.

II. The only known successful electricity market design is based on locational marginal pricing.

   A. The only design that fully integrates the economics and the physics.

Summary – The Importance of Coordination (Dispatch)

- For a number of reasons electricity is truly a unique commodity:
  - Limited storage means that current physical supply and demand must, within a narrow band, be equal to each other.
  - Production and consumption are interdependent.
- The commodity, i.e. electricity, at any point on the grid cannot be separated or defined independently of the path it took to get to that point.
  - Not like natural gas…or oil…or oranges…or virtually any other commodity where you can separate the commodity itself from the transportation.
  - This is the single most important characteristic of electricity from the perspective of non-discriminatory open access.
- What this means, is that the effect of the actions taken by the dispatcher in keeping supply and demand in equilibrium must be included in the price of the commodity, i.e. the price of electricity must include the effects of the dispatcher.
  - Put differently, the price mechanism should incentivize Market Participants to do what the dispatcher needs in order to keep the lights on, i.e., align the physics and the economics.
- Hence the importance of the dispatch function or equivalently, the method of managing transmission constraints.