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The must-run auction in an electricity market

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An unusual feature of spot markets for bulk electricity is that producers sometimes offer their output to the market at negative prices – in effect offering to pay their customers to take power. Such negative offers are fairly common in many electricity markets; they usually arise as a means of addressing the problem of large, inflexible thermal power plants which would be costly to shut down during periods of temporarily low demand.

We will call power generating capacity "must-run capacity" (during a given period of time) if its owners are willing to offer its output at a negative price for that period. (We will not be concerned with another problem to which the term "must-run" is sometimes applied – that of capacity which must necessarily be dispatched if all demands are to be met. In our must-run problem, the need to generate comes from the power plant itself – from the supply side, not the demand side.)

We consider the "centrally dispatched" or "pool" type of spot market for electric power, as operated in New Zealand, Australia, and some parts of the UK and USA. In this type of market, in a given time period, each node of the transmission network may receive offers from generating companies to inject power; each such offer takes the form of a (price, quantity) pair. At each node there may also be a demand for electricity; for our purposes these demands will be assumed to be inelastic. A central dispatcher must then solve a network flow optimization problem (the "dispatch problem") to decide which generator offers to accept in order to meet all the demands; the spot price of electricity at each node is the value of the dual variable corresponding to the demand constraint at that node.

Small amounts of must-run capacity can be absorbed in this market without difficulty. The market will (usually) still clear at positive nodal prices, and all generation owners, even those who offered at negative prices, will receive positive cashflow.

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But if enough negative offers are present, it may well be that the capacity they represent can already provide more than enough electricity to meet all the demands. Clearing nodal prices will then themselves become negative, so that increasing consumption or wastage at any node improves the solution. This creates a curious reversal of the usual market discipline – generators (at least in principle) pay purchasers for the privilege of supplying them, and the least efficient dispatch schedules are the most economically desirable.

At the same time, the dispatch problem becomes a genuinely non-convex optimization problem, which cannot be approximated by convex problems as other optimal power-flow problems often are. The market operator's task thus becomes computationally much more difficult.

In practice, it may be necessary for a power market to employ some kind of alternative or hybrid method to avoid having to solve a non-convex optimization problem during periods of low demand. The must-run auction is one such method, which has been used in New Zealand. Whilst a number of variations of the approach are theoretically possible, we will attempt to keep our analysis close to the scheme used in practice.

The mechanism begins by creating "must-run rights" and distributing them to generators in some fashion (e.g. by auctioning them off). A generator holding a given quantity of rights is permitted to offer a corresponding quantity of power into the market at a price of zero. All other generation must be offered into the market at some minimum postive price ϵ. (The value of ϵ is set at some token level, e.g. 0.001 cent/kWh.) The resulting dispatch problem, which has only non-negative offers, is then solved as usual. The quantity of rights created is limited (e.g. to 80% of forecast load) so that it will not be possible to meet all demands from zero-priced generation alone – thus ensuring that rights-holders are guaranteed dispatch.

In such a solution, prices paid for power are very low (of the order of ϵ at most) and the resulting cashflows are negligible. Generators willing to pay for dispatch of their must-run capacity do so through the auction mechanism for rights.

Suppose that must-run rights are allocated through a sealed-bid auction (as used in the New Zealand Electricity Market) and that demands are stochastic. Then the strongest possible assumption of competitive behaviour is that each infinitesimal "atom" of capacity enters a bid equal to its expected losses through not owning a right. A key point is that these depend on the allocation of rights to other generators. Under this assumption it is possible to find an allocation of rights representing an "equilibrium" in the sense that if there were a post-auction secondary market allowing further rights trading, no such trading would take place – each generator would consider its present allocation to be the most advantageous one, given the allocations to other generators.

An interesting feature of the equilibrium is that it may be sub-optimal for the system as a whole, despite the very strong assumption of perfect competition. This will be shown through examples.