

REVIEW OF POWER SYSTEM EXPANSION PLANNING IN VIETNAM

Tasks 1 and 2 Report

Prepared for

World Bank

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June 23, 2008

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INTRODUCTION

Scope of work

The objective of the work is to assess current expansion planning practices in Vietnam. This assessment comprises both technical aspects (methodology, planning criteria, construction of scenarios, sensitivity analysis and others) and evaluation of recent planning studies:

- The National Power Master Plan (PMDP);
- The hydroelectric power expansion plan, and Trung Son hydropower project in particular; and
- The thermal power expansion plan, and the Nghi Son project in particular.

In addition to the assessment of the planning practices, the work includes proposing a number of scenarios for the local consultant to carry out least cost runs including (if they have not been carried out previously) lower rates of demand growth, different fuel price assumptions and delays in plant construction, to assess the viability of specific projects without forcing them into the system plan.

This report is the deliverable for Task 1, with an overview and comments of current practices for system expansion planning, hydropower and thermal power planning in Vietnam.

An English translation of the master plan report prepared by IoE was provided to the consultant, including the relevant annexes giving detailed outputs from the modeling exercises. The consultant also reviewed other reports on planning practices in

Vietnam provided by the Bank. In addition, the preliminary results of the study by international consultant preparing an energy balance model were made available and reviewed.

Based on this review and international experience, the consultant has prepared this assessment of planning practices in Vietnam power sector.

The report also covers Task 2, by proposing and agreeing scenarios after meetings with IoE.

Organization of the report

Chapters 2 through 5 describe the current planning practices and the basic components and assumption of the IoE planning scenarios and outputs, namely: (i) load scenario; (ii) planning guidelines; (iii) planning objective and computational tools; and (iv) generation expansion plan.

Chapter 6 presents suggestions for sensitivity scenarios, used to evaluate the competitiveness of the Trung Son hydro project and the Nghi Son thermal project.

Load scenario

Load forecast is carried out in two steps: (i) short-term (2006-2010); and (ii) mid-term (2011-2025).

The short-term forecast is based on the aggregation of regional projections. In turn, the regional projections result from: (i) industrial development plans; (ii) infrastructure investments in city and rural electricity supply; and (iii) projections of household consumption.

For the longer term, the projections are based on elasticity coefficients which relate electricity consumption in each industrial and commercial sector to GDP growth rate. Due to the fast economic growth of Vietnam, and to the low initial consumption base, one can expect fairly high elasticity coefficients in the short-term forecast. However, it is very difficult to estimate those coefficients for the mid-term horizon, because the consumption structure of the economy will have changed substantially, and there is no data.

As a consequence, the elasticity coefficients for the mid-term are defined exogenously by IoE, based on comparisons with countries with GDPs today that are similar to the projected Vietnam GDP's for the different periods in the future.

Table 3.1 shows the GDP growth assumptions for the base case; the corresponding load growth rate (energy consumption); and the elasticity coefficient.

Table 3.1 – GDP and Load growth rates – base case

Period	GDP	Load	Elasticity
2006-2010	8.5%	16.0%	1.88
2011-2015	8.0%	11.0%	1.38
2016-2020	8.0%	9.1%	1.14
2021-2025	8.0%	8.0%	1.00

As mentioned, the elasticity for the first period (2006-2010) is quite high (1.88), and is progressively reduced as the country gets wealthier. Starting 2016, the elasticity coefficients are comparable to those of mid-income countries.

In the Consultant's opinion, it would be difficult to implement a more sophisticated load forecasting scheme, due to the above mentioned lack of data and to the deep

transformation of Vietnam's economy. The simple forecasting scheme used today has the additional advantage of making clear the exogenous assumptions. The procedure for peak load forecast is also straightforward; it basically assumes that the daily load shape will not change significantly along the planning period. Figure 3.1 shows the forecasted peak load growth rates for the base scenario.

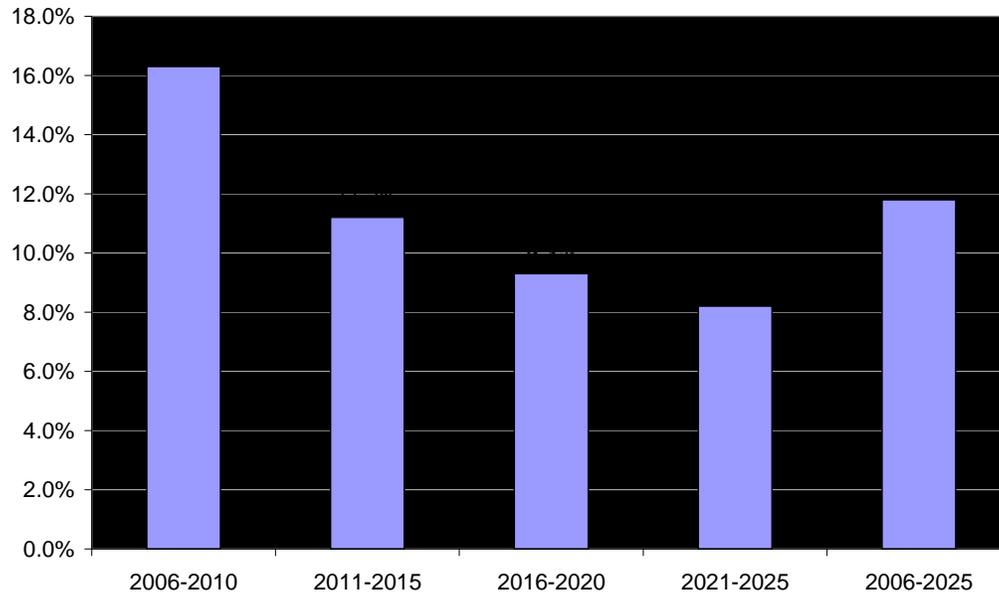


Figure 3.1 – Annual Peak load growth rates – Base scenario

Planning guidelines and Practices

Planning guidelines

According to information provided by IoE and their planning document, the following guidelines and issues were considered in the planning study:

1. Develop proportionally power generation in the North, Center and South regions, and ensure the reliability of the regional power systems and the national power system

Comment - The first part of the guideline (supply and demand in each region should be balanced) implies that developing local generation is assumed to be cheaper than importing power from a neighboring region (generation plus transmission cost), *for the same level of reliability*.

In the case of Vietnam, where the country is interconnected by a quite long 500 kV double circuit, this assumption seems to be reasonable; not only the cost of reinforcing the 500 kV circuit, but supply reliability issues (N-1 criterion) would possibly increase the cost. However, this type of expansion guideline should ideally result from a least-cost optimization of both generation and transmission investments, rather than as a priori constraint.

2. Ensure the suitable proportion of different power sources in each region and the whole country during the planning period.
 - a. Continue to expand gas-fired power plants in the South to utilize the natural gas resources and promote the discovery and development of other gas fields.

- b. Give priority to development of hydropower projects, especially multipurpose projects for flood control, water supply, power generation, etc.
- c. At the same time, there is a need to pay attention in development of coal-fired power plants, even in the South.

Comment: The diversification of generation technologies may be an effective strategy to hedge against uncertainties in fuel costs and in supply security. However, it is difficult to represent this type of benefit in the planning studies.

- 3. In each regional power system, it is prioritized to develop thermal power plants near load centers to reduce transmission of power.

Comment - As mentioned in the comment to Guideline #1, the economic advantage of developing generation that is closer to the load in order to avoid transmission costs should result from the least-cost plan instead of being used as a prior constraint.

- 4. Speed up the development of power projects in Laos and Cambodia to provide power to Vietnam, and import power from China.

Comment – Because the Laos and Cambodia power projects are likely to be hydro plants, it is easy to see potential advantages of this guideline, for example to reduce dependence on fossil fuels and to curb CO₂ emissions. However, the same rationale suggests that these imports should appear naturally as part of the least-cost expansion if they were included as candidates. If this does not happen, one would have the implicit cost of this national policy.

- 5. Support development of renewable energy projects such as small hydropower (up to 30 MW), wind energy, solar, biomass, geothermal, etc.

Comment - Same as in the previous case. In the Consultant's opinion, it may be interesting to estimate the cost of developing a national policy for renewable energy by comparing the least-cost expansion where those renewables are candidate projects with the expansion plan where they are pre-defined as projects to be built.

- 6. Take into account the possibility of delay in construction of power generation projects.

Comment – According to IoE, projects have historically taken longer to construct than assumed in the plan. One possible reason is that Vietnam has a limited number of construction companies which are building a large number of infrastructure projects and are thus over-extended. In the IoE planning study, this type of delay was compensated by requiring an “extra” reserve capacity margin. In the Consultant's opinion, it is not clear that this extra capacity would be the most economic option for the country, compared for example to the cost of reducing project delays (e.g. improve the project construction management, give more resources to the construction companies etc.), if feasible. In any case, it may be important to represent more realistic construction times for plants in the planning studies.

- 7. The power generation development program should be implemented at the least cost option with acceptable reliability of power system. Annual investment needs will be estimated for the planning period. The feasibility of mobilization of investment cost then will be reviewed based on the annual investment need.

Comment - This is the basic planning criterion for Vietnam: minimize the present value of investment plus expected operation costs, subject to supply reliability constraints.

- 8. In future, EVN will manage key projects such as Son La, Lai Chau, and nuclear plants only. Other power plants will be managed by JSC, private

sector and foreign companies (IPP, BOT, etc). A competitive power market will be gradually established and developed. The Master Plan therefore has to identify the role of each power plant type in the power system and its operation regime according to the demand load curve so that the Government can regulate the importance, specific responsibility and the reasonable power generation tariff of each power source which will ensure the reliability of the power system, and at the same time create the competition and improve economical efficiency in development and operation of power plants.

Comment – The purpose of the statement seems to be to clarify to investors which plants will not (in principle) be pre-selected for EVN, and make public investment opportunities to attract investment. Therefore, it may not be fully adequate to include it as a guideline for the planning study, because the ownership of a plant should not affect the least-cost expansion plan.

Planning practices

Based on the analysis of the documents provided by the World Bank, plus conversations with IoE personnel, it seems that generation planning in Vietnam does not have many degrees of freedom. The basic options (in increasing order of attractiveness) are hydro imports (defined by MoUs between governments); local hydro (not a large potential); local coal (not high quality, located in the North region); natural gas (fields in the South region, in the process of being developed) and imported coal.

Given the above constraints, planning becomes more a question of defining the entrance dates of the (few) available projects, rather than an economic choice from a very large number of options.

Regarding hydro projects, there is a great dependence of IoE on studies carried out by the construction companies. For example, IoE does not receive the “raw” hydro plant data (historical inflow records, operating characteristics of hydro projects such as minimum and maximum storage, downstream plants, hydro production curves, multipurpose uses etc.) for the candidate projects. These characteristics are summarized by tables with quantiles of energy and peak production (90% quantile; 75%; 50%; 25%; 10%).

As a consequence, it is not possible to assess whether the operation of hydro plants follows an optimal schedule; or if there is any hydrological diversity effect (the same quantile in the tables is used for all the country’s hydro plants in the studies; this is equivalent to assuming that the hydro inflows are perfectly correlated).

The coal and natural gas prices used in planning studies are substantially lower than their international prices. The reason seems to be that those prices are defined by government agencies and not represented as commodities. There also seems to be some coordination issues between the natural gas sector and the power production sector. When asked why no more natural gas plants were included in the plan, IoE stated that they used the gas quota that was produced by PetroVietnam. However, the gas sector expansion plan states almost the opposite: that the gas consumption for the power sector was calculated with basis on the number of gas-fired plants required by the power expansion plan.

Finally, there is an explicit concern about fuel supply security. For example, plants using imported coal are only considered if they have 15-year firm fuel contracts.

Planning objective and computational tools

As seen in the previous section, the national master plan practice uses a least-cost planning criterion: minimize the present value of investment plus expected operation costs, subject to supply reliability constraints and, as seen in the previous section, other energy security guidelines set by the government.

Conceptual planning scheme

A generation expansion planning process can be *conceptually* implemented in the following steps:

1. Determine a candidate expansion plan
2. Calculate the supply reliability indices for the candidate plan of step 1
3. If the supply reliability is acceptable, go to step 4. Otherwise, return to step 1.
4. Calculate the total cost of the candidate plan: sum of the present value of the investment costs and the present value of expected operation costs
5. If the total cost of the candidate plan is lower than that of the best plan obtained so far (incumbent plan), make incumbent plan \Leftarrow candidate plan. Return to step 1.

Computational tools

The key computational tools used worldwide in power expansion planning studies are:

1. Production costing;
2. Reliability evaluation; and
3. Calculation of the least-cost expansion plan

IoE also uses such tools in their planning studies, as will be detailed next.

Production costing

The calculation of expected operation cost requires a *probabilistic simulation* of system dispatch, taking into account uncertainties in generation availability; in the inflows to the hydro plants; and in the load levels.

According to IoE, three computational tools are used for this probabilistic simulation:

- The dispatch module of WASP III;
- The dispatch module of Strategist; and
- The PDPAT 2 program.

Two of the tools – WASP III and Strategist – are well known commercially available software packages. The third tool, PDPAT 2, was developed by the Tokyo Power Corporation.

All of these tools use an analytical convolution scheme, where the generation units are added to the system by increasing order of variable operating costs, and the probability distribution of the load yet to be supplied is calculated. An approximated hydro operating policy known as “peak shaving”¹ is used to represent the effect of hydro plants in the convolution scheme (it is not clear how wind power, which is not

¹ In the peak shaving scheme, the hydro plant production is always used in the highest load levels, with the objective of having a “flat” load profile for the thermal plant dispatch.

dispatchable, is represented in the probabilistic simulation). In the case of Strategist and PDPAT 2, it is also possible to represent economic power exchanges among the regions (North, Center and South), taking into account transmission constraints. In the Consultant's opinion, the use of a convolution scheme to model hydroelectric plants and other renewables such as wind power may not be fully adequate in some systems. In the case of hydro plants, it is possible that the optimal operating policy for the hydro plants, based on their water values², departs from the peak shaving scheme. For wind power, it may be necessary to represent the chronological sequence of wind variation.

Suggestion: Because modeling inaccuracies may affect the competitiveness of these important generation sources and therefore their selection in the master plan, a validation of the current convolution-based production costing approach is recommended, through the use of chronological hydrothermal simulation models which represent in detail the reservoir operating characteristics and use streamflow sequences.

Reliability evaluation

The same tools used for probabilistic production costing can also produce supply reliability indices. For Vietnam, the current adopted index is LOLH, expected number of hours with a supply interruption. The reliability criterion is that LOLH in each region should not exceed 24 hours per year.

Suggestion: the same concerns on the need to validate the convolution-based schemes when there are hydro plants and wind power apply to the supply reliability evaluation. The same chronological hydrothermal simulation suggested for assessing the production costs also represent random generation equipment outages, and can thus be used for assessing the convolution-based reliability calculations.

Calculation of the least-cost expansion plan

Both WASP III and Strategist use a dynamic programming (DP) scheme to determine the least-cost expansion plan. In this scheme, each candidate technology is represented as a "state variable", and the investment decisions for each year are how many "units" of each technology should be installed.

The DP scheme works reasonably well when the expansion options are thermal plants. The reason is that these generation technologies are naturally modular, and thus easy to represent as state variables (build one coal plant; or two; or three etc.).

² Although a hydroelectric plant has no direct operating cost (apart from a small variable O&M cost), it does not mean that it should be used first in the economic dispatch. The reason is that hydro plants have storage reservoirs, and can thus delay their energy production to the future, where the economic advantage of producing energy is higher. This transfer of energy can be as short as from off-peak to peak hours or as distant as three or four years in the future. In all cases, the guideline for deciding whether to generate now in the hydro plant or to postpone its energy production is given by the plant's *water value*. The so-called *immediate water value* is the opportunity cost of generating now; in turn, *future water value* is the expected opportunity cost of using the hydro energy in the future. The optimal production schedule is the one that equalizes the immediate and future water values (the exceptions are when the reservoirs reach its storage limits).

As in the case of production costing and reliability evaluation, the representation of hydro plants in the DP scheme is more complex, because they are not modular (each hydro project may have different hydrology, reservoir, etc). Also, it is not possible to represent each hydro candidate as a separate state variable, because the number of combinations would increase exponentially.

An approximate solution to this problem is *pre-order* the hydro plants by a *cost-benefit index* (CBI), for example, the ratio of investment cost to firm energy. In this case, the state variable for hydro investment in the DP scheme is: build the hydro plant with the best CBI; then the second best; and so on.

The current planning practice seems to have adopted a prior ranking of the hydro projects (Table 7.2, general ranking of hydro power plants in IoE planning study). According to the document, the ranking criterion comprises both economical and environmental / social impacts. However, it is not clear if the ranked hydro projects have been formally represented as a state variable in the DP scheme, or if the starting dates of hydro plants are input to the plan as fixed decisions.

Finally, it is not entirely clear whether WASP III or Strategist have been used as the main models for the least-cost planning study. In the beginning of chapter 7, it is (correctly) mentioned that WASP III cannot represent several interconnected regions, as required in Vietnam. Figure 7.1 then shows a diagram in which WASP III is used to provide a “least-cost starting plan” which is then (manually?) refined through analysis with the multi-region production costing / reliability analysis of PDPAT 2. In section 7.1.2, however, it is claimed that the model Strategist, which does have the ability to simulate interconnected regions, has been used to produce the least-cost expansion plan.

Conclusions

The computational tools used for the production costing/reliability evaluation and for expansion planning are well known commercial products. However, further assessment would be needed on whether the probabilistic simulation technique used in these models for calculation of expected operation cost and supply reliability (analytical convolution with “peak shaving” for hydro plants) provides the most adequate representation of hydro plants and wind power in Vietnam. Because modeling inaccuracies could affect the economic evaluation of those important generation resources, a “benchmarking” of the hydro production with chronological simulation tools with representation of hydrothermal optimization is suggested. The dynamic programming (DP) technique used for determining the least-cost expansion plan is also well known. As in the case of production costing, this DP technique is easily applied when the candidate projects are thermal plants. When there are hydro plant candidates, a pre-ranking of the hydro projects by a cost-benefit index is usually carried. However, there is the concern that this pre-ranking may not lead to the optimal solution.

Generation expansion plan

Criteria for assessing the generation expansion plan

It is naturally very difficult to evaluate in detail a complex expansion plan as the one for Vietnam. However, it is possible to calculate some overall indices that verify some characteristics of a least-cost expansion plan

- *stability of reserve margin* – although the optimal installed capacity in each year may vary as a function of the technology mix, this variation should be reasonably small. Depending on how tight the current supply situation is, this stability may only be reached after some years in which the adequate reserve margin is gradually restored.
- *stability of supply reliability indices* – because the objective is to minimize the sum of expected investment and operation costs, subject to reliability constraints, the supply reliability indices should tend to be the same (or very similar) in all regions and years. As in the previous cases, the supply reliability may be inadequate in the first years of the planning period, and gradually reach the adequate levels.
- *equality between short- and long-run marginal costs* – a well known mathematical property of least-cost expansion planning is that, at the optimal solution, the expected short-run marginal cost (SRMC) is equal to the long-run marginal cost (LRMC). The SRMC is a by-product of the production costing models, whereas the LRMC can be calculated from the plan results.

Stability of capacity reserve margin

Figure 6.1, prepared by Peter Meier, a World Bank consultant, shows the capacity reserve margin (installed capacity - peak load) for the base case scenario.

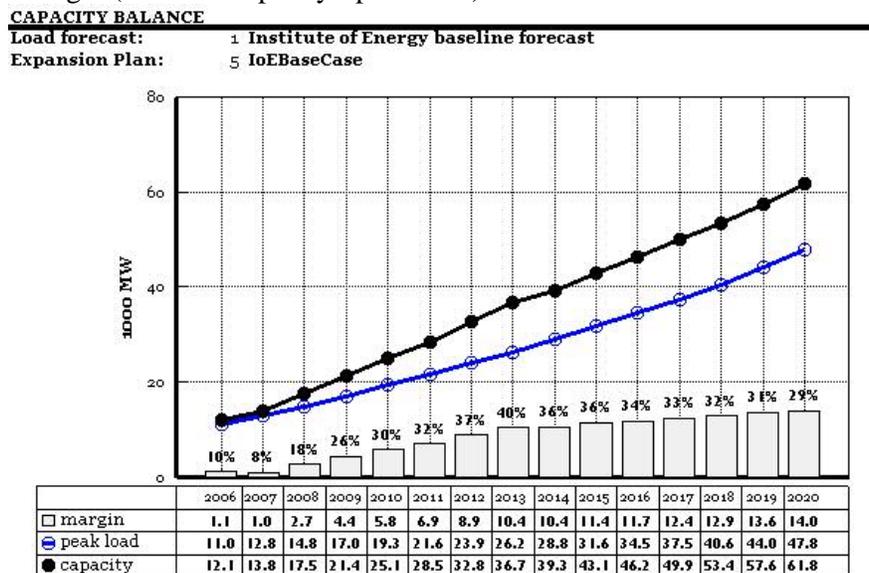


Figure 6.1 – Reserve Margin

We see in the Figure that the % reserve margin is low in the initial years. This is consistent with the current supply situation, which is very tight. As new generation is built, the reserve margin stabilizes around 35%.

Stability of supply reliability indices

As mentioned previously, the current supply reliability criterion is:

LOLH (number of hours per year with load shedding) ≤ 24 for each region

Figure 6.2 shows the resulting LOLHs for each region (North, South and Central) in the base case, provided by IoE.

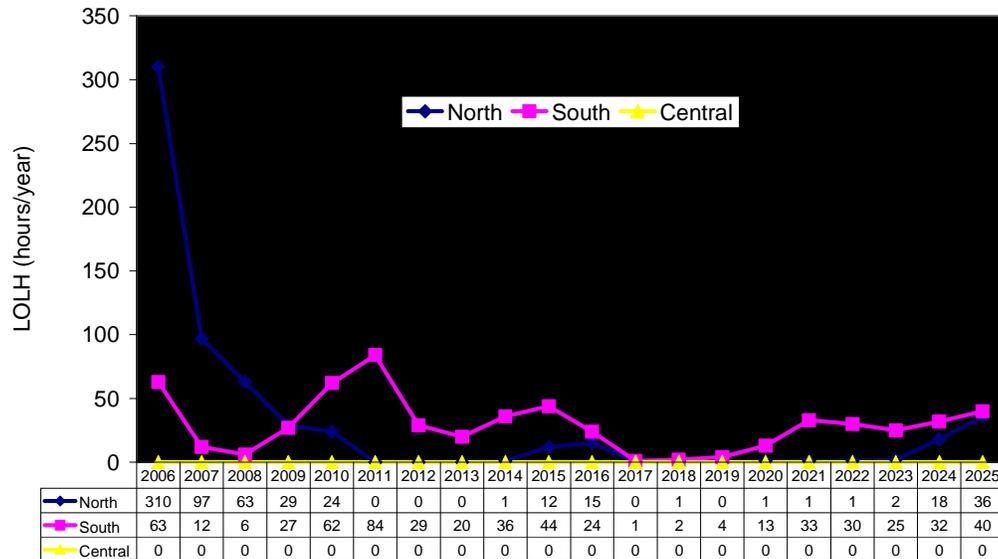


Figure 6.2 – LOLH reliability indices – base case

As shown in the Figure, LOLHs in the North region are smaller than the 24-hour target from 2011 to 2023. One possible explanation is that the optimal economic solution (minimum investment + operation cost) led to an “overcapacity” from the reliability viewpoint. This could happen, for example, if new capacity displaced the dispatch of inefficient existing generation (high operation cost), which still remained available as a reliability asset.

The opposite pattern is observed in the South region: with the exception of years 2017-2018, the LOLH indices tend to be high, violating the 24-hour criterion in most years. Given that the least-cost expansion model would build capacity – even if it is expensive – in order to comply with LOLH criterion, one possible explanation is that not enough candidate projects were available to the model in those years.

Finally, the Central region presents zero LOLH for all years. Given that the Central region depends on imports from either North or South in different seasons, it is not clear why the reliability algorithm would give priority to its supply.

Equality between short- and long run marginal costs

Figure 6.3 shows the annual short-run marginal costs for the base case (values provided by IoE, who is preparing the long-run marginal costs).

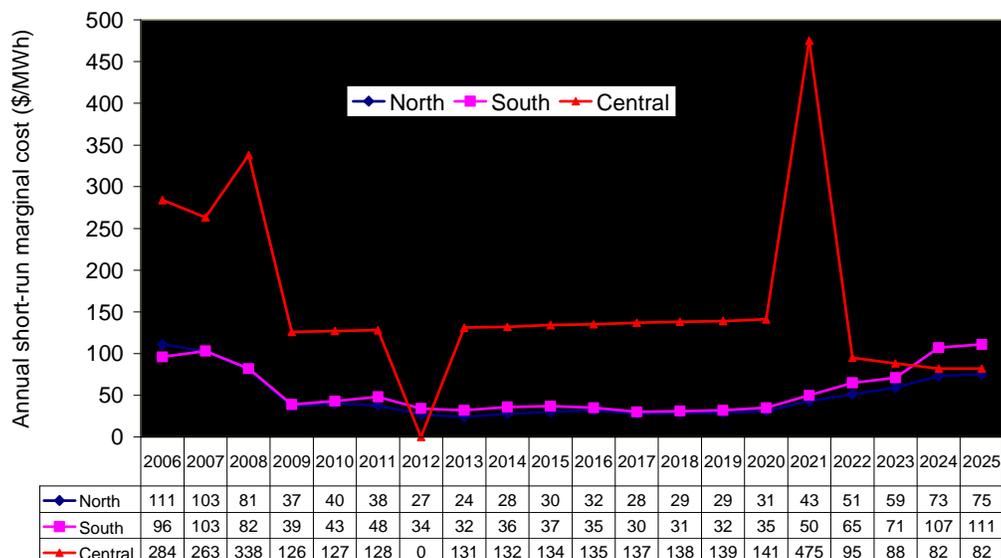


Figure 6.3 – Annual short-run marginal costs – base case

We see in the Figure that the SRMCs for the North and South region are balanced and around high 30s \$/MWh. The values for the Central region are much higher and show some anomalous behavior such as a low value of zero \$/MWh in 2012 and a high value of 475 \$/MWh in 2021. IoE has been asked to investigate those issues.

Sensitivity scenarios

The key parameters for a generation project competitiveness are fuel cost (\$/fuel unit) and investment cost (\$/installed kW). Although both parameters have changed since the preparation of power master plan, it is felt that the escalation of fuel prices was more significant, and may have a bigger impact on the relative competitiveness of projects.

As a consequence, the first sensitivity analysis concerns the price of coal (21 US\$/ton) and the price of natural gas (3.2 US\$/MMBTU). It is suggested that the expansion plan should be re-run with new prices: 80 US\$/ton for coal and 7 US\$/MMBTU for natural gas.

It is expected, as a result, that the hydro plants will be become more competitive. As a consequence, they should have earlier entrance dates in the least-cost plan.

The second and third sensitivity studies concern the economic attractiveness of the Trung Son hydro project and the Nghi Son thermal project. It is suggested that the least-cost plan be re-run with each project fixed at its earliest possible date. The total cost will then be compared with the reference plan, which was produced in the first sensitivity study.

The fourth sensitivity study concerns the effect of construction delays. It is suggested that the reliability evaluation and production costing be run for the optimal plan of sensitivity analysis #1, but where all the new plants have a one-year delay in its operation start date.

