Proposal

The Development of a Regional Gas & Electricity Resource Decision Support System (DSS) for the Russian Federation

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INTRODUCTION

Proposed Work

Develop a trade and infrastructure decision-support system to optimize energy resource utilization and risk management for the natural gas & electricity energy sectors in the Russian Federation. The proposed work will focus on the modeling, analysis and optimization of two interrelated aspects in the planning and maintenance of the Russian natural gas transmission network. The two aspects that will be investigated are an economics/trade aspect and a surety aspect. It is proposed that models of the existing Russian natural gas transmission network be constructed with Purdue University's Power Pool Development Group doing the economic model and Sandia Laboratories' Risk and Reliability Department doing the surety model. Once constructed, these models can then be analyzed with each organization's respective tools. With an eye towards balancing economic returns with surety concerns, vulnerabilities or opportunities for improving operations and for future construction can be found. Tradeoffs between the two aspects can also be made for present operations and maintenance and future construction.

Typically for success in an international cooperative effort such as this, it is imperative to have equal partners set up in the respective nations. This function will be accomplished by performing this work under the auspices of the Institute for Risk Mitigation (IRM)—a partnership between Sandia National Laboratories (SNL) and the Russian Federal Nuclear Center of Experimental Physics (VNIIEF). Under this umbrella, work can be effectively parceled out to organizations with communications established and maintained between the cooperating parties both here in the US/North America and in Russia/Europe.

The Russian Federation has a vested interest in seeing this work performed. It will aid in bringing safety and reliability improvements to their most precious export commodity of natural gas. It will increase productivity in the use and export of their vast natural gas reserves which will translate directly into increase generation of revenues. Also, an effective DSS will increase the Russian influence in the European energy markets that can enhance its stature in both Europe and around the world. This work will also redirect scientists within MinAtom from defense-related work in order to undertake solving their domestic problems.

The United States indeed has a motivation to undertake this proposed work because it addresses its strategic goals in the Energy arena. First improving the surety of the natural gas transmission pipeline infrastructure can reduce the release of methane and help achieve the reduction of greenhouse gases into the atmosphere[1]. By effectively and intelligently introducing more natural gas into the European energy mix, it is possible to affect a reduction in the European need for oil that can reduce pressures on the world oil

[1] Estimates of pipeline losses in Russia vary from as low as 1% to as much as 20% of natural gas throughput lost to the atmosphere. Note that methane is 20 times more potent in trapping heat as a greenhouse gas than carbon dioxide.

markets. It can create intellectual capital that is grown both here in the US and in the RF through this cooperative research and development. From within this intellectual capital, developments in environmental-friendly natural gas technologies can be harvested for use here in the US.

There is little usefulness in the creation of these models unless a mechanism is found to act on the results of such models. Consequently it is proposed that in parallel with the development of these models there be consultation with a regional advisory energy committee consisting of energy policy makers from each of the countries of the region. The insights gained from the models for energy policy makers in the east and the west of the region can then be discussed and assist in regional policy formulation. Conversion of the insights from the model into action items for the energy trading partners is a top priority of this proposal.

Background

Worldwide dependence on oil from Middle Eastern OPEC states gives rise to problems of vulnerability and economic insecurity. The role of natural gas in reducing this energy dependence has superceded the role that had earlier been anticipated for nuclear energy, and natural gas has become an important alternative energy source.

Current prices of natural gas in Western Europe are double those in Eastern Europe. The trade of natural gas is therefore likely to increase dramatically as the costly and more limited sources of Western Europe are depleted and the vast natural gas resources of Russia are brought to market as a result of improved marketing structures and greater transmission opportunities. But the European Union's efforts to liberalize its internal gas market and to stimulate the participation of other natural gas producers such as Turkmenistan, Iran, Azerbaijan, and Libya may also serve to cut gas prices and reduce the revenues of its current largest supplier, Russia, which already supplies 30% of the EU's imports

Loss of revenue to Russia would be a very unattractive development since it needs capital to maintain and expand its pipeline network. Because it has not been able to make needed repairs to its network, Russia has stated that it will cut production this year and seek to obtain gas from Turkmenistan to meet internal and international commitments. However, this may not succeed, because Turkmenistan would prefer to sell to Iran and Turkey, who pay more and pay 100% in hard currency.

Longer term, Russia may meet increasing demand by taking advantage of the retreating ice pack to develop Arctic sources such as the Rusanovskaya field in the Kara Sea and by transporting the gas to Europe via pipeline from the Yamal Peninsula, providing of course that the costs can be met. Sections of the Yamal-Europe pipeline have already been built in Germany, Poland, and Belarus and linked to Russian fields using joint-venture agreements to cover costs. There are no such agreements, however, for the

Russian sections, and it remains to be seen how these as well as the Kara Sea fields will be developed.

Once production and transmission facilities are developed, however, Russia would be in a position to exert even greater influence on global energy markets. Increased dependence on Russia might not be welcomed in Europe. Indeed, the nature and extent of its dependence on natural gas imports will become of great strategic importance to Europe and the stability of existing and future gas-producing nations will represent a significant concern.

For Europe, the problem to be solved is that of meeting its increasing demand for energy without increasing its concerns over dependence on outside producers, in particular, Russia. For Russia, the problem to be solved is that of generating the revenue needed to pay the costs associated with maintaining and expanding its energy industry in order to meet the increasing demands of its own internal market as well as the European market.

The answer, perhaps, is to strive for a level of cooperation and collaboration among users and producers with regard to energy trade and energy surety such that a market develops with sufficient diversity of suppliers to allay European concerns and of sufficient breadth and potential to attract capital investment in the expansion of Russia's energy industry.

Although Russia has heretofore limited direct foreign investment in its natural gas industry, it plans to increase this limit over the next four years. Most likely, investment and collaboration will take the form of joint ventures (e.g., Blue Stream line from Russia to Turkey under the Black Sea and German, Polish, Belarussian sections of the Yamal-Europe line) and multi-national consortiums (e.g., Yamal-Europe line).

For the most part, these collaborations have been arranged on a project-by-project basis. What is needed is a level of cooperation and collaboration that extends well beyond present-day joint ventures and consortiums to achieve a more integrated, wide-ranging perspective that encompasses the production, transmission, and distribution of natural gas and electricity within and across multiple regions of the RF, and eventually, of Europe as well.

Motivations

The efforts of this international team would be directed to the development of an improved gas and electricity decision support system. The system would be based on an integrated model of energy trading and energy surety that incorporates data from all pertinent regions, thereby providing a necessary tool to aid in making decisions about energy investment, trade and infrastructure. To our knowledge, this effort would be the first to combine a detailed economics model to a detailed infrastructure surety model that would be capable of evaluating tradeoffs between two competing energy resources.

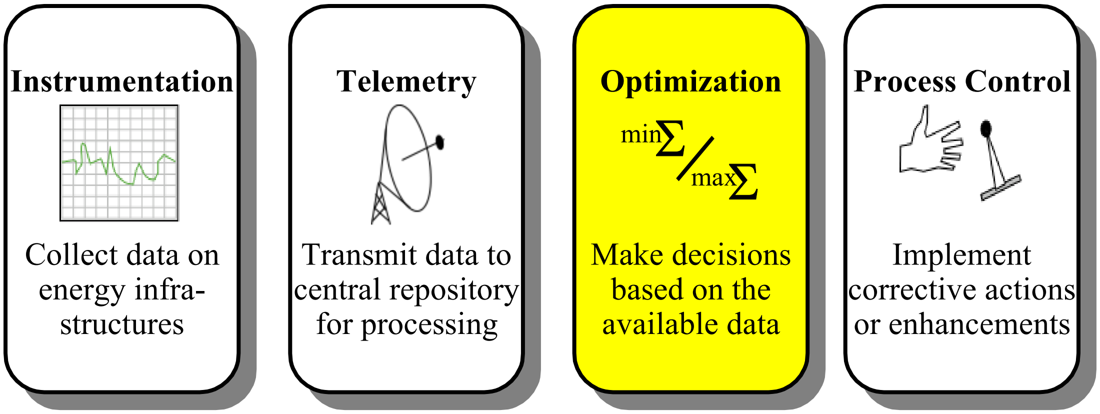

Figure 1. Vision for a Natural Gas Infrastructure Management System

In Figure 1 above, a vision is laid out which captures the long term potential in developing such a decision support system. The optimization panel in yellow indicates the initial efforts to be made in this proposal with the available data being a snapshot in time and thereby *static* in nature. A more appropriate view of optimization's place is in a *dynamic* system, one that is in constant flux day to day, hour to hour, minute to minute, that shows real-time capture of data and the capability to make control decisions that can be implemented immediately.

This work, while being a worthy effort, cannot be performed for its own sake. The two major stakeholders, the United States and the Russian Federation, will have to have their needs in this area be addressed by all of the work being proposed. Indeed, the proposed effort is attuned to the interests of both the RF and the US as shown in Figure 2 below.

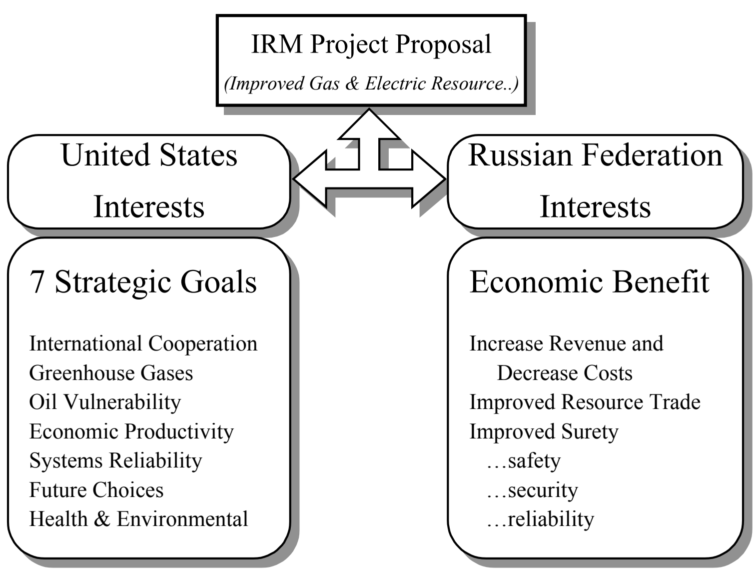

Figure 2. Proposal's Complementary Nature In Meeting Two Interests

More detail showing how these interests are addresses is detailed in the following sections.

U.S. Motivations

In the first half of 2000, the DOE convened three expert stakeholder panels to determine whether the DOE Energy Resources R&D Portfolio proposed for Fiscal Year 2001 was likely to produce results leading to significant progress toward meeting seven strategic goals. The assessment indicated that two of the goals, *International cooperation on global issues* (Goal VI) and *Expansion of future energy choices* (Goal VII), were inadequately addressed. Three of the goals, *Enhanced surety (reliability, safety, and security) for energy systems* (Goal III), *Reduced impacts on health and the environment* (Goal IV), and (global) *Stabilization of the concentrations of greenhouse gases* (Goal V), were addressed in only a partially adequate manner. Finally, two of the goals, *Improved economic efficiency of the energy supply and of end-use systems* (Goal I), and *Reduced vulnerability of the U.S. economy to disruptions in oil supply* (Goal II) were adequately addressed.

The work proposed here contributes beneficially not only to the inadequately and marginally addressed goals but also to those that were adequately addressed:

This project is all about international cooperation (Goal VI). Thus, contributions to this goal are without question. The US is committed to addressing global issues through international cooperation. This cooperation is obviously accomplished via collaborative work with key foreign research groups on projects of mutual interest. Some specific objectives of the International Clean Energy Initiative for countries in transition are to reduce methane emissions from pipelines and to encourage development of natural gas grids. In addition to the linkage to the stated objectives of the International Clean Energy Initiative addressed by this project, another motivation with respect to international cooperation is to build intellectual capital in Russia on non-defense technologies.

Moderating the global greenhouse gas loading(Goal V) attributed to the Russian natural gas pipeline system is the strongest direct, tangible motivation for the U.S. participation in this project. This project could contribute strongly to a regional solution to a truly global challenge. Controlling methane emissions in Russia could have a noticeable positive impact on the U.S. economy if policy options such as emissions trading and the Clean Development Mechanism actually become a reality under international agreements such as the Kyoto Protocol.

Increasing the exportability of Russian natural gas by improving the integrity of the Russian pipeline system and understanding (optimizing) international trade options will reduce the pressure on world oil supplies because of substitution of natural gas for oil, particularly in Europe. Reducing the pressure on global oil supplies certainly lowers the U.S. vulnerability to oil supply disruptions (Goal II) since the U.S. is a large oil importer and, thereby, competes for the available oil supplies globally. This motivation is a strong one, in general, and is particularly timely given the current state of world oil markets.

Certainly, natural gas pipeline safety (Goal IV) is an important issue that has been called into national (U.S.) prominence by the recent disaster in Carlsbad. One mechanisms by which modeling the Russian pipeline system will improve pipeline safety in the U.S. are challenging to articulate is through the transfer of knowledge to the U.S. based on the Russia work. To the extent that this project helps facilitate the development of environmentally friendly technologies related to the operation of natural gas pipelines, some benefits may accrue to the U.S. by domestic applications of these technologies.

There is the possibility of transferability of the modeling capabilities developed for the Russian system to the modeling needs related to the U.S. pipeline network in the systems reliability are (Goal III). Modeling of the U.S. pipeline system is an important need for reliability, safety, and economic reasons, especially as natural gas becomes increasing the fuel of choice for electricity production. This coupling of the natural gas and electric grids should be a fertile area for modeling and simulation of the U.S. energy infrastructure.

Increasing the exportability of Russian natural gas into world markets will increase the foreign exchange available to Russia. This situation strengthens the Russian economy and provides dollars for purchase of imported goods and services. Consequently, U.S. exports markets in Russia should expand, thereby generating wealth in the U.S. economy (Goal I).

R.F. Motivations

Fundamentally, Russia is interested in maximizing the difference between revenues and costs in the natural gas and electric power energy sectors. To do this, both energy trade and energy surety considerations must be taken into account. These entail modeling efforts that make possible energy system simulations that examine the approaches to minimizing both the *costs* and the *risks* of energy delivery. Given this capability it is possible to address critical issues by posing and answering key questions, such as

- What are the gains from trade associated with additional RF production and concurrent expansion/refurbishing of the gas pipelines connecting RF and Western Europe?
- How do these gains compare with the gains associated with refurbishing/expanding the electric transmission/generation system between RF and Western Europe?
- What combination of electric/gas refurbishment/expansion maximizes the gains from trade between RF and Western Europe?
- Regardless of the situation, how shall these gains be shared between exporters, wheelers, and importers to achieve both equity and efficiency goals?
- What is the impact on these gains of various country autonomy/self reliance constraints that limit dependence on foreign sources of energy?

- How can the energy trading system be set up to encourage market forces to work most effectively to discover efficient projects/trades?
- What investments in both the gas/electric systems are robust, in the sense that they are part of the optimal solution under a whole range of scenarios?
- How will the environment be affected by these developments? Who are the environmental gainers/losers?

The Russians also seek an improvement in the safety and reliability of the gas delivery system and the electric power grid. Russian natural gas has to travel many kilometers to reach its ultimate consumers throughout Europe so there is an increased potential for reliability problems for the simple reason that more pipeline means more opportunities for failures. The capability to effectively improve reliability can potentially save billions of cubic meters of gas per year that, instead of ending up in the atmosphere, is converted to usable heat or electricity.

Both the US and RF have a real interest in the redirection of Minatom personnel from work in defense to energy sector projects that this proposal will provide. There is nothing novel in repeating that very capable Russian scientists and engineers with expertise in weapons-related fields need something to do. These personnel will have to work somewhere eventually and work such as is being proposed will give them the opportunity to make important contributions for their own country.

By improving all these aspects just described, the RF can enhance their global trade stature, in particular, in Eastern & Western Europe.

Approach

Scope of the proposal

This proposal is intended to be the initial stages of a multi-year project that will combine the expertise in energy, surety and economics from organization both here in the U.S. and in the R.F. The primary participants will include Sandia National Laboratories (management and surety), Purdue University (economics and energy trading), VNIIEF (management and modeling), Gazprom (Russian natural gas) and RAO ES (Russian electricity). To address the problem of how to best to distribute the vast natural gas resources of the Russian Federation, we propose to look at gas pipeline/electric power grid reliability along with its vulnerabilities while keeping a very close eye on the economic realities in the RF. The expected results of this proposal are an integrated model of Russian energy flow and infrastructure with aspects of both surety and economics embedded within it. From this modeling effort, optimization and simulations can be assembled and run to determine the best strategies for maintenance and repair, energy resource trading, and future investment.

In its initial phase (first eighteen months), the effort would consist of data collection, refinement of the energy trading and surety models to accommodate the data, integration of these models, and proof-of-principle simulations to demonstrate optimization with respect to both energy economics and energy surety. The first phase would also initiate the development of the technologies for smart pipes that can monitor gas flow and third-party contacts in real time; robots that can perform internal detection and repair; systems that can remotely detect methane emissions. The long-term vision for the management system includes instrumentation, telemetry, and process control, in addition to the modeling/optimization capability. The IRM would function as the operational and training center within which these capabilities would be exercised.

Economic Trade Modeling and Analysis

In a perfect world of free trade in any commodity, price differences between countries should not exceed the cost of moving the commodity from the low to the high cost area. If this is so then trade can take place, since the gains from trade exceed the costs of trade, setting in motion a sequence of events that stops only when the energy supply price and falling demand price differ by the transportation cost.

The Power Pool Development Group (PPDG) at Purdue University has, for the past four years, been taking advantage of the enormous body of data readily available on the costs of electricity generation, transmission, and distribution in both Southern and West Africa to build energy trade models for their respective power pools. These models have shown the advantages of such trades. Initial results show that magnitude of the gains from trade when adopting a regional approach rather than a country-by-country approach can be enormous. The Southern African Development Community (SADC) integrated rationalization expansion plan compared with the country-by-country investment plan saves in the order of 13%, or $1.63 billion savings for the time horizon 2000 to 2016. Previous studies by Purdue indicate that generally one can expect 4% to 8% savings by joint dispatch of electricity alone given a fixed network, rather than each utility meeting its native load from its own generating plants [3]. The existence and use of a combined natural gas and electricity regional trade model provides investors with a level playing field to compare competing generators and transmission proposals (lines and pipes).

Modeling Methodology

Two parallel models are to be built for this model. An electricity modeling methodology is ready for FSU and Central Asian data. Work has started on developing a methodology for modeling natural gas transmission and trade in summer 2000. The proposed modeling system captures the dynamic interactions between customer demand, the utility's operating and investment decisions, and customer rates by cycling through the various sub-models until an equilibrium is attained. The Purdue modeling system is unique among utility forecasting and planning models because of its comprehensive and integrated characteristics including generation, transmission and financial variables and parameters.

The model to be used is a version of the standard dynamic production /transportation /consumption model found in the mathematical programming literature. (The first formulation of the problem was contained in an article "On the Translocation of Masses" published in Russia in 1939 by Serge Kantorovich.) The model is spatial, with a set of production/consumption/storage nodes connected by a set of arcs. Initially in what follows, the model is a short run model, in that the capacities of the system are fixed; later, this will be relaxed to allow expansion of capacity.

Purdue will develop electricity and gas trade models to determine pattern of gas and electricity shipments and capacity expansion plans within the study area which meet the study area's growing demand for electricity and natural gas over a long-term horizon (eg. 20 years) at least cost. Within the area, a region consists of one or more countries; each country or region within a country is modeled as one node. In the base case, free trade is permitted to take place between all of the nodes.

The current total electricity demand for representative hours, days the supply of natural gas and other fuels used to generate electricity has to be known for each node, as well as forecasts of the growth of each over the planning horizon. The current shipping capacity (of electricity and natural gas) between any two nodes/countries also has to be known, as well as estimates of line loss, and gas storage capacity. Specific plans for the expansion of existing capacity (new generation stations, new gas wells, new transmission and new gas pipelines) are all needed. The importance of these required model inputs will direct the first year effort to focus on data collection and preliminary model development.

The collection of data from each utility and government within the region will be the major task of the first year. A regional workshop is also proposed for the first year at which a regional advisory energy committee will be established. An important part of this workshop will be a data collection seminar (2 days duration) to train key collaborators in the region on the needs of the model and to understand all the definitions of the model notation/parameters. Making contact and developing a working relationship with the two key massive institutions (GAZPROM and RAO ES) in Russia for gas and electricity data will be a watershed achievement for the whole of the work with the RF. It is hoped that participants from these two institutions will also participate at the workshop as well as colleagues from VNIIEF.

Construction of an initial regional natural gas and electricity transmission model and identification of regional data collection consultants will also take place in the first year. First year runs of the preliminary models for the region will serve to demonstrate the policy usefulness of the model. Issues include determining the relative merits of shipping gas directly to electricity generating stations at demand points over gas transmission lines versus generating electricity at gas well mouth sites, and shipping electricity, rather than gas to these same demand points, as well as other energy trade issues identified as the project progresses.

Tasks to be accomplished by the Purdue team during the first year of the effort include;

1. Completion of a debugged and fully documented initial model of gas/electricity transmission for the region
2. Collection, through key collaborators, of an initial data set to populate the model
3. Representative runs of the model to show the policy usefulness of the model

Visits to the region to work with FSU scientists to insure the direction of the project remains relevant to the real energy policy issues faced by decision makers

Surety (Safety, Reliability, and Vulnerability) Modeling and Analysis

[Sandia description of the modeling, analysis, optimization, etc.]

Russian Partners Contributions

[Need VNIIEF input here]
Data collection, gas leak monitoring technologies, modeling of the actual networks?, additional to-be-determined initiatives

Integration of Surety, Economics, Russian Technology

[Given the previous three sections of proven modeling technologies, here's how we would propose to integrate them into a larger systems analysis and]

Management Structure

A. Program Elements

Work breakdown structure with ISC overseeing work in the US and RF. Specify which work each organization will be responsible for performing.

B. Cooperative details

Working with VNIIEF, Gazprom, delegates from European countries. Purdue can provide info on experience collecting data in Africa. Discuss how all these entities can be brought together to focus on the problem at hand.

C. Cost Breakdown

Budget, organizations, people, travel, etc. Preliminary budget will have to be on the order of $3million/year.

D. Schedule

Breakdown of activities, milestones, and deliverables.
Year 1…Year 2…Year 3…

APPENDICES

United States Perspective

The state of the US energy transmission system is in flux, particularly with respect to natural gas and electricity generation. Current production of natural gas in the United States is around 20 trillion cubic feet (Tcf) per year. As the fossil fuel that releases the least amount of the greenhouse gas CO_2 per unit of energy released, natural gas as an energy source for electricity generation is expected to replace nuclear as the "alternative" energy source of choice for the foreseeable future. In the meantime, the electric power industry is undergoing deregulation, which has engendered a trend toward a more distributed power system. An important component of this distributed power system will most likely include low-cost electricity generated by new combined cycle gas turbine electric generation units. As a result, it is currently estimated that 6 Tcf/year (out of a total projection of 32 Tcf/year) of natural gas will be required for electric power generation by 2020.

As more electricity is generated using natural gas, the gas and electric sectors will become increasingly interdependent. Unfortunately, unless steps are taken, gas and electricity needs will not be met; the infrastructure as it exists today simply cannot support the expected growth in annual demand, especially with large seasonal demand swings. New pipelines and transmission lines will need to be put in operation in an environment that has seen construction costs quadruple in the past four years. Pipelines are aging with an estimated loss of 0.3 Tcf during gas movement from field to end use—this loss will only increase in the coming years without intervention. Moreover, the current regulatory and competitive environments may discourage the gas industry's investments in new technology, which can only hinder its ability to address pipeline degradation.

In view of these realities, critical issues for the US in the areas of natural gas and electricity are:

- Growth of distributed power
- Making efficient use of existing pipes
- Gas storage
- Aging pipelines.
- Balancing use of energy sources

R&D initiatives that address these issues are needed in the following areas:

- Capacity expansion
- Integrated electric and gas grid modeling
- Use of robots to assess and repair pipelines
- Remote monitoring of pipeline integrity and CH_4 emissions