Automated Power System Planning

G. L. Lebby
Machine Intelligence and Power Associated Research Group
Department of Electrical Engineering
North Carolina Agricultural and Technical State University
Greensboro, NC 27411

Abstract

As electric utilities grow in size and complexity, planning for future expansion and system security has become increasingly complicated. The cost of making corrective changes in the power system has made it necessary for utilities to consider long-range design options and to perform detailed computer studies when considering network modifications (especially when the modifications will have a large impact upon system performance and overall operation.) To assist engineers in system planning, an Automated Power System Planning (ASP) tool that uses machine intelligence concepts is presented. In response to system planning scenarios imposed by a system planner, the ASP will propose corrective planning options, based upon expert knowledge in the power system planning field, known physical constraints, and historical system information.

1 Introduction

The electric utility industry has an obligation to serve as an adequate and reliable source of electric power at a reasonable cost. As the need for electric power increases, the need for generation, transmission and distribution capacity also increases. The specific changes to be made in the electric power utility resources (to meet the rising demand) are determined during the system planning process. During the system planning process, there are obvious factors taken into consideration, such as: determining the minimum reactive power required; ascertaining equipment limits; determining the generation available from the various units; analyzing the character and size of loads at different points in the system, etc. Less obvious factors that affect system planning, such as the existing system, voltage stability, harmonic stability, load growth due to increases in population or the level of economic development, etc., must also be taken into consideration.

Power system planning activities in general may include load forecasting, generation planning, transmission planning, subtransmission planning, distribution planning, operations planning, fuel supply planning, and environmental planning [1]. In developing the automated power system planning (ASP) tool for Bonneville Power Administration (BPA) the main considerations are those associated with transmission planning 1. Many analytic tools have been developed to help system planners deal with transmission planning. Power flow routines are one of the most important analytic tools for helping power system planners solve for the power flow and bus voltages by analyzing the system in steady state. Figure 1 shows an example of a small power system displaying static power flows. Transient stability routines and optimum VAr placement routines are also helpful to the power system planner in terms of giving insight into system behavior follow system faults and determining the best placement of static VAr devices respectively.

The analytical routines involved in estimating power flow and performing transient stability simulations are very complex and involve solving very large systems of non-linear algebraic equations. In addition to the nonlinear system equations, there are factors that are difficult to define in the context of a strictly mathematical model (Figure 2.)

- environmental constraints,
- social and political constraints,
- financial and economic conditions [2, 3].

Current power system planning tools are generally analytic in nature and do not include the difficult factors mentioned above in arriving at a best solution.

---

1This research is funded in part by Department of Energy Contract Number DE-B179-91BP20900.
In order to incorporate the difficult factors, new power system planning tools must be developed that incorporates heuristical methods of reasoning used by human power system engineers.

Machine intelligence is a relatively new area that is being applied to power system planning. Some early works involves adapting expert systems [5, 6, 7, 8] and fuzzy logic [9, 10]. The end-goal of the ASP is to integrate some of the non-obvious system planning concerns in achieving an acceptable system planning solution.

2 Problem Identification

The problem faced by the developers of the automated power system planning (ASP) tool is to capture the essence of a power system planner in a software system. The problem domain of the software system would capture those qualities of the power system planner that would allow him or her to find the optimal plan for system operation and construction [4]. Some typical qualities of a power system planners are:

(1) familiarity with the system network that he or she is working with (this familiarity may include historical knowledge of the system, present knowledge and anticipated future growth and development);
(2) a basic understanding of power systems often coupled with many years of experience;
(3) power system intuition on when and where to implement corrective action (in this case, the intuition is backed up by looking at the results of various diagnostic software tools.)

The long-range concern of the ASP tool is to advise system planners of system configurations that would lead to a reliable, economic and stable system operation.

3 Software Foundations

Present day power system planners have various analytical software tools that are at their disposal for analyzing the condition of the power system. These tools include power (load) flow, optimal VAR placement procedures, transient stability routines, etc. The ASP tool design emphasizes utilizing the wealth of previous procedures and tools that are currently used by the power system planner (Figure 3.)

The ASP tool design primarily addresses concerns of steady state power system operation. Steady-state contingencies are exposed by the BPA Power Flow program through calculating (or failure to calculate)
the full AC power flows, bus voltages, line currents, and fast outage results. The ASP will function as a system planner's aid in interpreting the results contained in multiple runs of the PowerFlow. The initial direction and limits of the runs are supplied by the system planner via the system user interface.

The traditional power system planning tools will be used by the ASP in testing hypotheses concerning system modification and voltage stability. The tools that will be initially considered by the ASP are:

1. BPA Power Flow Program - program performs the steady-state analysis of the electric power system.

2. CEPAL Shunt VAr Support Planning Program - program performs optimal sizing and placing of VAr devices considering a cost objective function.

3. Other programs (needed by BPA System Planners) to assist in solving the system planning problem.

4 ASP Tool System Description

Traditional power system software incorporates problem specific knowledge and the method of reasoning (expert wisdom) in such a manner that these two parts of the problem solution are virtually inseparable. Modification of either problem specific knowledge or the method of reasoning (due to software extension, more knowledge of the problem, etc.) could lead to difficult software changes.

A knowledge based power system planning tool is formulated where there is a clear separation between the domain specific knowledge and the inference mechanisms (expert system criterion.) This separation of function allows the software system's inference mechanism to switch among the domains of process data collection, user interface concerns, voltage instability studies, and optimal (tolerant) VAr placement studies without changing the inference mechanisms (which are geared towards emulating a system planning expert.) By the same token, the inference mechanisms may be changed without changing the domains of specific knowledge [7].

The ASP tool is sectioned into four functional layers:

1. The Graphical User Interface Layer;
2. The Automated System Planning Core Layer;
3. The External Procedure Reference Layer;
4. The Historical Database Layer.

The layer that end-user comes directly in contact with is at the graphical user interface (GUI) layer. The GUI presentation is responsible giving the end-user a convenient way to control the underlying expert system, and giving the end-user portals into the underlying system layer functions. The GUI layer also contains modules for communicating with ASP expert system. The GUI may be hosted on any machine connected to the network upon which the rest of the ASP tool is also connected. Multiple GUI sessions are scheduled and controlled at the ASP expert system layer.

The ASP expert system layer contains routines that perform process control for multiple GUI sessions as well as the planning expert system. The ASP expert system layer contains an extended system study database, based upon expert knowledge and data gathered from the engineers at BPA as well as fundamental knowledge of power systems and circuit theory. This layer will also have facilities that will allow the ASP tool to run external routines necessary to complete the system planning function. These external procedures will perform power flow runs, optimum VAr placement and transient stability analysis. This layer of the ASP model will be able to retrieve information from various historical network databases.
The historical database layer will contain information on the power system under study including device characteristics, geographical information, environmental information, etc. The historical database will also contain information on past system simulations where applicable.

The ASP tool will be implemented using the C programming language. The core routines will be stored on a networked DECStation 5000/240 workstation running an Ultrix operating system. The GUI will run as an application under OSF Motif. An machine capable of supporting X-Window and Motif should be able to serve as a ASP GUI server. The GUI will be tested by using a networked VAXStation 4000/60 running a VMS operating system.

5 Concluding Remarks

The technical objective of this research is to provide Bonneville Power Administration with an artificially intelligent software system, called an Automated Power System Planning (ASP) tool, that will combine the heuristic knowledge of system planning experts (at BPA) for the purpose of completing portions of a system planning project that are subject to computational redundancy. In formulating the ASP, both passive and active methods of extracting information from the system planners will be used.

References


