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Reference 17

FLORIDA POWER AND LIGHT'S SYSTEM CONTROL CENTER FUNCTIONS

The functions performed by the System Control Center (SCC) are divided into two broad categories: those that are necessary and critical for the instantaneous operation and control of the power system, and those that enhance the effectiveness of the operators by providing the tools necessary to make more meaningful decisions. The former functions are resident in the Quad portion or "front-end" of the system, mainly because they require computer equipment that allows high-speed, efficient processing of information on a real-time basis, while the latter are resident in the Cyber portion or "back-end", for these require computer hardware and software capable of handling large, highly complex programs. Each major function is briefly described below.

QUAD FUNCTIONS

Data Acquisition/Monitoring

The principal functions of Data Acquisition and monitoring subsystem are to collect raw analog and digital data from remote terminal units (RTU's) located at substations and plants, convert the data to engineering units, check the data for alarm conditions and disseminate the data to the data base, where it can be utilized by other functions. The manner in which RTU data is obtained and monitored is determined by the type of equipment from where the data originates.

Alarm Display/Control

This function creates alarms which direct the operator to those areas where his attention is required. All alarms are displayed in the Alarm Summary Display and printed at the time of occurrence and upon returning to normal. Each alarm is directed to a prespecified CRT console.

Alarms are categorized as status alarms, which have two possible conditions, such as breaker position, and analog alarms, used for telemetered quantities which may take on a number of values, such as the ampere flow on a line.

Status alarms are classified into those that do not have a definite normal and alarm state, such as breaker position, and those that do, such as high oil temperature. Position devices are alarmed only when the status changes on an unauthorized basis, while the remaining status alarms are produced when these are not in a normal state.

Every telemetered analog quantity, such as MW, MVAR, amps, and KV, has a high limit and a low limit. An alarm is produced when these limits are violated. Telemetered analog quantities may also have up to three levels of significance alarming. Each significane alarm indicates the level traversed expressed as a percent of the quantity's high limit.

Area Monitor Program

This function calculates the real-time values of interchange, generation, and load for areas of the FPL system. It computes inter-area power exchanges and inter-system power exchanges. The computed quantities are displayed and checked against operator entered limits. When limits are violated, alarm messages are produced on CRT alarm displays and on selected loggers.

There are three sets of areas: the Minor Area set, the Major Area set, and the Security Area set. Areas in each set are non-overlapping and encompass the entire FPL system. There is a maximum of 10 Minor Areas, 6 Major Areas, and 3 Security Areas. In addition, each Major Area is some combination of Minor Areas.

MVA Calculation

This function performs the calculation of the MVA flow through up to 300 transformers. The MVA flow, while not telemetered, is required in the data base to monitor transformer overloads. The MVA values are computed either using the transformer's MW and MVAR flows, or if these two quantities are not available, by the use of voltage and current flow through the transformer.

The MVA values are displayed and are alarmed and logged when the limits are violated.

Load Frequency Control

The Load Frequency Control (LFC) function operates in conjunction with the on-line Economic Dispatch (EDC) program to regulate the power output of generators within FPL in response to system frequency, tie line loading or a combination of these to maintain scheduled interchange and frequency. This regulation is done in the most economic manner possible consistent with the operating limitations of the units and varous security constraints. The program will result in corrective control information to the 55 dispatching units under control.

Economic Dispatch

The Economic Dispatch (EDC) allocates generation to be dispatched in an optimal manner among all generators being controlled, so as to minimize system production cost, while maintaining FPL's spinning reserve requirements. The EDC program passes the desired generation values for each unit to the LFC functions where these are used as one of the guidelines to regulate the generating units such that system demands are satisfied most economically.

A similar program, in algorithm and structure, computes each unit's ideal economic generation values every five minutes. This ideal economic dispatch operates without any of the security constraints under which the real time EDC operates when system overloads are present. The ideal EDC values are passed to the Production Cost program for cost comparison between the actual and the ideal conditions.

Net Interchange Scheduler

This program performs two functions: provides data for the computation of the instantaneous desired net interchange required by the LFC function; and maintains the necessary records for costing and billing transactions. The program is able to handle up to ten types of transactions with 18 different companies.

Reserve Monitor

The Reserve Monitor Program computes five reserve values for the FPL system: spinning reserve, supplemental reserve, available dispatch generation, operating margin, and daily operating reserve. Spinning reserve and operating margin are also calculated for each of up to the six major areas defined in the Area Monitor Program. In addition, the spinning reserve contributed by each unit is computed and displayed.

System and area reserve values are displayed on the reserve summary display. Furthermore, reserve values are checked against dispatcher entered limits. Insufficient reserve quantities create alarm messages.

System Status Processor

The System Status Processor (SSP) analyzes the open/close status of switching devices (breakers, switches, etc.) to determine the electrical configuration of the network and to generate in or out of service information for the elements of the power system. It provides output for alarms, the dynamic mapboard driver, and for system overview displays.

Production Cost Program

The Production Cost Program computes fuel production and total operating costs (fuel, plus operating and maintenance) for each unit, each class of unit (fossil, nuclear, GT, etc.) and for the entire FPL system. These costs are computed on an hourly basis and are printed on hourly and daily logs.

This function will compute both actual and ideal production costs. Actual production costs are based on the actual generation values, while ideal production costs are based on the result of the periodic ideal economic dispatch.

The Production Cost Program also provides cost information for both actual fuel usage (i.e., gas plus oil) and the corresponding cost for oil consumption only.

Energy Accounting System

The Energy Accounting System runs every hour to collect MWH data from generation and tie pulse accumulators. With this data it performs the necessary calculations to support several FPL logs, among which are the Interchange Energy Accounting Log and the Inadvertent Energy Accounting Log. The Interchange Energy Accounting Log shows the hourly energy received and delivered over each tie and for the FPL system. In addition, it shows the net sum of the receipts and deliveries for all ties and for the FPL system. The Inadvertent Energy Accounting Log depicts the difference between the energy scheduled for the hour and the actual energy delivered or received during the hour. The inadvertent interchange for each hour is passed to the Load Frequency Control Program for automatic correction if so specified.

The Energy Accounting System also runs every minute to integrate tie line MW values. The integrated tie line, MWH data is compared to the respective pulse accumulator values and the difference is displayed on the Tie Summary Display. Large differences indicate erroneous tie line readings.

Gas Usage Accounting Program

The Gas Usage Accounting Program is responsible for collecting raw gas flow data from generating unit pulse accumulators every five minutes, for converting this data to gas consumption data, for storing 24 hourly usage readings, and for creating all the data required by the hourly gas usage log and the daily gas usage log. This function runs every five minutes and creates a current gas usage display at that time. Two other displays report gas usage past history. Unit gas consumption values for the last eight hours can be reviewed and/or edited on the Gas Usage Past History Display, while the Past Usage Display summarizes usage for the last 1, 4, 14, and 24 hours.

FPL Logs

This function allows the user to create and edit log formats which will be printed on an hourly or daily basis. All log formats are created by a programmer/engineer on a CRT. The printout of a log is identical to the CRT display of the log. Where a log warrants a width of more than 72 columns two associated CRT formats may be used, and the printout will resemble the side by side display of the CRT's. In reference to hourly logs only, the specific hours of the day a log is printed is selectable.

The operator will be able to display and edit the data contained in a log on a CRT display. Hourly logs will be available for display and editing for one hour and daily logs will be available for display and editing for a twenty-four hour period. When a log is edited, a recalculation will take place for any other system data that the modification affects, including data in other system logs.

The periodic logs that are scheduled automatically hourly or daily by this function are:

System Summary Daily Log
System Generation Daily Log
Daily Gas Usage Log
Interchange Schedule Summary Log
Napsic Performance Log
Inadvertent Energy Accounting Daily Log
Interchange Energy Accounting Daily Log
System Summary Hourly Log
System Generation Hourly Log
Hourly Gas Usage Log

In addition, any CRT display can be printed as a periodic log by entering the display number on the appropriate hourly or daily log menu.

Value Trending/Recording

This function allows the operator to assign any dynamic status, analog, or calculated value in the system to any of the assignable pen recorders or to a CRT trend plot.

The system has one single-pen, twelve dual-pen, and one multipoint recorder. Of these, three dual-pen and eight of the twelve points in the multipoint recorder are assignable. The high and low scales on each value to be recorded are enterable and may be modified while the recorder is operating. Outputs to the pen recorders are at four second intervals.

CRT trending simulates strip chart recording with time on the horizontal axis from left to right and amplitude on the vertical axis from top to bottom. The plot is interruptable, so that the CRT can be used for other purposes, with recall as if were never interrupted. Up to 16 values may be trended; however, data may be collected for up to 24 unique points. This allows data collection while all plots are busy. Outputs to the CRT trend is at one of nine selectable discrete time intervals. Points to be trended together must have the same time base, but not the same horizontal scale. When the plot is full, the two oldest points will be discarded, and the graph is shifted to the left, allowing space for two new points.

Disturbance Analysis

The Disturbance Analysis Program collects data prior, during, and after a system disturbance. Up to 300 data values may be identified as disturbance data (e.g., Turkey Point No. 3 MW generation, Sanford frequency, Davis 138KV bus voltage, Dade-Lauderdale 230KV line MW flow, etc.) for storage purposes. Disturbance storage may be triggered after exceeding one of the following limits:

Absolute value of frequency
Prespecified value of ACE
Prespecified value of Actual Net Interchange
Prespecified rate of change of Net Interchange

It may also be triggered by the "anded" combination of any two of the above triggers, by a manual entry, or by the unauthorized change of any of up to 24 positional devices, such as a generator breaker.

The data identified as disturbance data is continuously stored in 10 second snapshots in a circular file which holds 30 copies of these snapshots (5 minutes). When a disturbance is detected the collection frequency is increased to two seconds for a minimum of six minutes of data and a maximum of ten minutes of data.

Selected reports may be logged by specifying the class of the desired data to be retrieved, such as generator data or line flows. Up to 15 of these classes may be specified. A composite report of all 15 classes may also be produced.

Historical Storage and Retrieval

The Historical Storage and Retrieval function collects, stores in magnetic tape, and allows retrieval of system data.

System analog data may be collected at five different rates: 10 seconds, five minutes, 15 minutes, one hour, and daily. Status data for positional devices (e.g., breakers) will be stored only on change during each hour, and in total at the beginning of the hour. It is estimated that no more than one magnetic tape per day will be used.

All data retrieval is done from the off-line Cyber. Data may be retrieved by specifying the following:

- Time Period: From date 1, time 1 to date 2, time 2
- Interval: Retrieval frequency (greater than or equal to collection frequency)
- Class: Up to 15 categories (e.g., all unit MW, all voltages)
- Point ID: A specific point (e.g., 138KV bus voltage at Dade Substation)
- Restriction: Data is retrieved only when certain conditions are present (e.g., Turkey Point No. 3 MW generation when system frequency is less than 59.9 hertz).

Miami SCADA

This function provides the Division dispatchers the ability to remotely control equipment located at substations located in Dade and Broward counties from the control center. The dispatcher may control breakers, regulator blocking, switches and other on/off devices. In addition, the system controls tap position on autotransformers and allows the start and stop of gas turbine generators.

Load Management

The Miami Load Management Program actuates, under dispatcher control, the shedding and restoration of load during periods of load reduction. It controls groups of feeder breakers. These groups are in turn organized into levels. These are up to ten levels with up to 150 load groups each. Each group is composed of up to four breakers.

The Miami Load Management Program tabulates for each group and level the amount of load shed and sheddable. It also keeps track of the last interruption and the duration of the interruption. In addition, when a group is shed, the interruption duration is continuously updated every minute and the time of the last interruption is updated. After 30 minutes of interruption, a reminder alarm message is output for that group if it has not yet been restored.

Load shedding may be on a level or a group basis. Load restoration must be on a group basis, although individual breakers may be controlled from the Load Management Display.

CYBER FUNCTIONS

MODEL UPDATE

The Model Update function is responsible for maintaining the real-time configuration of the power network for use by real-time network analysis functions (State Estimator, Bus Load Forecast, External Model Computation, Security Analysis, Network Sensitivity Calculation and Security Constrained Dispatch).

Network data is available from several sources. Network topology and normal status of breakers, switches, etc., are always available from the Network Data Base. Real-time status and analog measurements are obtainable on request from the QUAD SCADA functions. Further, manual entries of status external to the SCADA system may be made from one-line displays associated with the Model Update function.

At the start of each real-time network analysis sequence, Model Update programs obtain the latest data from each of its sources and construct a single bus-oriented model of the entire network (both FPL and external companies). Bus sections which are connected by closed devices are sorted into single buses to reduce the dimensionality of the network to manageable proportions.

Economy A

The Economy A Program is designed to allow a dispatcher to rapidly investigate the economic aspects of a prospective Economy A interchange transaction. Economy transactions (FPL Schedule C) are mutually desirable to two utilities when one of them is able to produce and sell power to the other cheaper than what the other can produce it for. Economy A transactions are normally for the next hour and are not of sufficient magnitude to require commitment of units.

This function allows the dispatcher to simultaneously investigate the cost or saving of up to ten increments of interchange in the "purchase" direction, and ten in the "sale" direction, with a specific company.

Because this is a study program, it can also be used as a study economic dispatch and production cost function for future conditions.

STATE ESTIMATOR

The purpose of the State Estimator program is to provide a complete power flow solution for the FPL system from the real-time measurements. The major characteristics of the real-time measurements are that they are noisy but redundant. The redundancy permits the program to improve the estimate of the solution beyond that given by the measurement.

The major function of the State Estimator program is to filter noisy telemetered data, to estimate values of missing telemetered data when there is adequate redundancy, and to detect anomalies (metering errors) caused by improper meter calibration or incorrect network modeling.

The State Estimator solution provides an "accurate" system to the operators for monitoring. The solution is used by the External Model Computation program to integrate the internal FPL real-time solution into the total network representation and generate an overall solution for the total network.

The State Estimator program provides the real-time internal (FPL) system solution for the Security Analysis program, for the Security Constrained Dispatch program, and for the Network Sensitivity program.

EXTERNAL MODEL COMPUTATION

The External Model Computation function provides a complete power flow solution for the system modeled in the FPL Network data base. The State Estimator function solves a subset of the total model; the State Estimator solution then is treated as a solved portion of the network by the External Model Computation program, which uses standard power flow techniques to solve the remaining (or, "external") portion of the model.

The result of the External Model Computation function is a real-time network description with a complete steady-state solution. This solved real-time network is created automatically and solely for the use of the Network Sensitivity, Security Constrained Dispatch, and Security Analysis functions - no direct operator control is provided.

External Model Computation processes the solved real-time network to produce data to support two different displays. One display gives an indication of how well the State Estimated solution compares with the solution of the external model. The other display contains messages identifying the overloaded branches and out of range voltages. This second display provides the dispatchers with the capability of monitoring voltages and flows at locations not monitored by the SCADA system, such as distribution stations on transmission lines.

NETWORK SENSITIVITY

The Network Sensitivity function operates from the solved real-time network which is produced by the External Model Computation. It determines, for the present state of the system, the sensitivity of losses in the network to changes in unit generation and interchange.

These sensitivities are calculated in order to supply penalty factors for use in real-time by the Economic Dispatch function and for use in study mode by the Unit Commitment function and the Economy A function. (Sensitivity of losses to unit output converts directly to penalty factors.)

The Network Sensitivity function is executed automatically as part of the real-time network analysis sequence. It performs a supportive role to other applications - it has little direct significance for an operator and thus has very little in the way of man-machine interface.

SECURITY ANALYSIS

Security Analysis is designed to assist FPL personnel in determining the security of the system under both a single contingency criterion (one branch or generator outage) and a limited number of double contingency (one branch and one generator) criteria. This program executes on a real-time basis and/or on a study basis.

Security Analysis operates upon a solved power flow network. In real-time, this network comes from the External Model Computation; in study, the network comes from the Power Flow. Security Analysis then makes high speed approximations to the AC solution for the specified sets of outages (the outage List) to be simulated.

In real-time, Security Analysis can be executed upon either an operator request, a time trigger (every 30 minutes), or an event trigger. In study, Security Analysis executes only on operator request.

In real-time, the outage list is augmented by those branches which are already overloaded. These are detected by the External Model computation function and passed to Security Analysis.

For each outage simulated, elements are checked for limit violations (i.e., line and transformer overloads, generator reactive limit violations). All outages which cause violations are output along with identification of the violations and information on the magnitude of the violation. In this manner, only the important results are seen by the operator.

The maximum number of entries are 500 in the outage list (460 single outages, 40 single unit and single branch outages) and 300 in the Violation Check List.

SECURITY CONSTRAINED DISPATCH

The Security Constrained Dispatch function operates on the solution provided by External Model Computation. It determines, for any such solution which has overloaded branch elements, what constraints should be placed on specified unit outputs in order to alleviate all overloads. If elimination of all overloads is not possible with the specified controls, Security Constrained Dispatch finds the unit constraints which most nearly achieve the objective (i.e., minimization of line overloads in the most economical manner).

Two modes of use are provided in the function. Under normal conditions the function will be enabled in the event an overloaded branch is detected in the solution of External Model Computation. When such an event occurs, Security Constrained Dispatch will automatically calculate unit constraints (i.e., unit limits) and if the operator desires, will transfer those constraints to the AII functions for use in LFC.

It is also possible for an operator to disable automatic running of Security Constrained Dispatch and use the program under manual control. In this second mode, the operator may study control action necessary for simulated outages which cause violations (as detected in Security Analysis) in addition to studying controls for the current system conditions.

BUS LOAD FORECAST

Bus Load Forecast provides the capability to generate a forecast of the substation MW and MVAR loads and of the time-switched breaker positions (open or closed) for specified hours. This function operates on a real-time mode as well as on a study mode.

In the real-time mode forecasts are genenerated for the current time and day type using current system load. One MW and MVAR value will be forecasted for each load. All time-switched breaker positions will be forecast for the current hour. This capability is used by the External Model Computation program to schedule the loads at all buses external to the State Estimator model.

In the study mode, all individual loads represented in the entire network (FPL and external companies) are forecasted for a specified hour. To accomplish this, Bus Load Forecast utilizes input from the System Load Forecast Program. The forecasted station loads are then utilized as input by the Optimal Power Flow. This allows the representation of future load patterns as a function of FPL load. In addition, this function also allows the operator to forecast all loads at a specific substation for one entire day (This day must be within the next seven days).

SYSTEM LOAD FORECAST

The System Load Forecast program is designed to produce system load forecasts for FP&L's hourly integrated system loads for the next one to seven days.

The System Load Forecast function is executed by operator request via the CRT. The resulting set of hourly load forecasts can be displayed at the CRT for the dispatcher's review, adjustment, and subsequent storage. The load forecasts are used as input for the Unit Commitment function and the Bus Load Forecasting function.

The forecasts are based upon dispatcher-entered weather forecasts from four locations (e.g., Miami, West Palm Beach, Daytona and Ft. Myers) and on the most recent system loads. The model utilized is updated automatically at the end of each day by the use of exponential smoothing techniques. Exponential smoothing is an averaging technique which progressively discounts old data.

UNIT COMMITMENT

Unit Commitment determines the optimal generation schedule for a period of up to 7 days. The optimal schedule is the hourly commitment and dispatch of FPL units which minimizes the system operating cost while observing numerous operational requirements and constraints. The operating constraints recognized by this function are: generation requirements, reserve requirements, unit priority order (computed by the program), unit minimum up and down time, and unit capabilities.

This function also provides the operator a means of overriding the results from a Unit Commitment run and recosting the modified schedule. This feature is called "operator participation". With this capability available to the operator, conditions that were not modeled in this program itself can be handled through direct operator intervention.

In addition, the program also computes the optimal gas allocation among gas burning units given a commitment and dispatch for the entire planning period. A set of system, area, plant, and unit gas constraints are observed by this function.

Unit Commitment obtains: unit status data, interchange transaction schedules, and past gas consumption from AII functions; FPL's load forecast for up to seven days from the System Load Forecast function; and penalty factors from the Network Sensitivity function. Unit Commitment provides: a unit commitment and unit loading for any hour selected by the Optimal Power Flow function; and two of up to four complete outputs to the Commitment Comparison function.

Unit Commitment is executed by operator request via the CRT.

OPTIMAL POWER FLOW

The Optimal Power Flow function provides the capability for operators to study the steady-state operation of the power network under postulated conditions. An optimal power flow (as opposed to a power flow) means that in addition to finding how a network will behave under specific conditions, one can also ask what conditions should exist to provide the best possible operation in terms of cost, security, or a combination of these two.

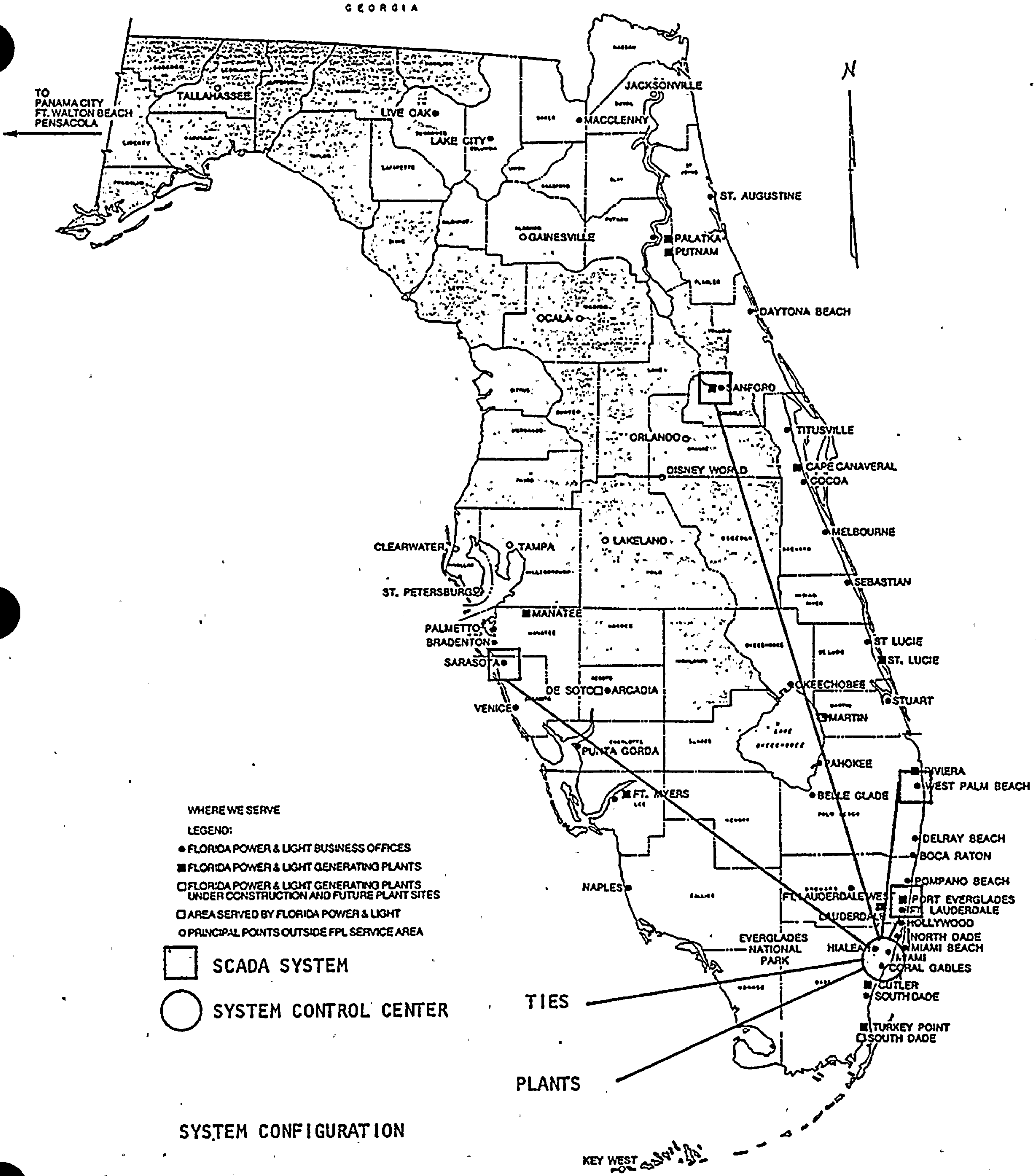
The Optimal Power Flow makes extensive use of data from other functions: Model Update makes real-time logical device status and TCUL positions available to this function; Bus Load Forecasting distributes the system load in the network; Unit Commitment provides FPL unit outputs, FPL's load, and FPL transactions for the hour requested by the Optimal Power Flow.

The results of the Optimal Power Flow are used as input for the study mode of the Security Analysis program.

The following cases may be investigated with the use of this program: simulating the expected operating conditions during some future time; finding the most economic pattern of generation which will satisfy load and interchange without violating network limitations; finding the most economic settings for reactive controls (TCUL taps and generator reactive output) which will satisfy system-wide voltage constraints.

DATA MAINTENANCE

Data Maintenance provides the means of entering and updating all the non real-time data required by application programs. Through this function the network description, as well as the physical characteristics of its elements (lines, generators, etc.), is checked for errors and introduced into the computer system.



SYSTEM CONFIGURATION