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BALDR-1: A SOLAR THERMAL SYSTEM
SYSTEM SIMULATION

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Component models in POWER were written in several levels of detail according to their impact on plant performance. The engine efficiency model is a function of hot engine temperature, cooling tower temperature, and the load at each time step. The thermal and electrical energy storage residence losses are calculated based on the amount of energy in storage at each time step. The auxiliary electrical loads are calculated based on plant capacity and actual plant output at each time step. The electrical transport efficiency is based upon electrical current flow through the transport system. The component models for thermal and electrical storage charging and discharging, the electrical generator, power conditioning, the inverter and the converter currently use a constant average efficiency. The component models may be easily increased in accuracy if necessary or desirable for a particular application.

The POWER code calculates the electricity delivered to the grid at each time step and sums it for one year. The total electrical energy delivered during the year is divided by the total electricity which would have been delivered had the plant operated at rated capacity for the entire year. This yields the plant capacity factor.

This capacity factor is calculated for each plant described by an element of the three dimensional matrix of collector field sizes (AC), thermal energy storage sizes (ST), and electrical storage sizes (STE).

Matrices of the operating mode of the plant and the dispatch of electrical storage at each time step can be output. The calculated capacity factor, along with the corresponding collector field size, thermal storage size and electrical storage size, is output for use by the ECON code. In addition, the plant rated capacity and generator size are output for use by ECON.

ECON CODE

The ECON code includes two major subroutines (COST and BUSBAR) which are based on computer codes originally written by JPL (Ref. 2,7). Using the output from POWER, ECON determines a capital cost, a life cycle busbar energy cost, a simple payback period, and annual operations and maintenance (O&M) costs for each plant configuration based on either the thermal energy or the electrical energy produced.

Subroutine COST uses unit costs as inputs to determine the cost streams for both capital expenditures and O&M. Capital costs are determined for each of four subsystems: 1) collector and receiver, 2) electrical and/or thermal storage, 3) power conversion, and 4) miscellaneous (including land, thermal and electrical transport, and spares and contingencies). These costs are currently distributed over the plant construction period as a uniform series of payments. With slight modifications to the code, COST could create a nonuniform cost stream.

Operations and maintenance costs are also determined in COST. Currently, O&M is a uniform stream of annual costs for each year of the plant's lifetime. In case a specific schedule of required maintenance is known, COST can be modified to produce a nonuniform O&M cost stream. Alternatively, a periodic maintenance cost could be added onto the annual O&M cost stream currently produced by COST.

Subroutine BUSBAR is based on the Utility-Owned Solar Electric Systems (USES) model, a conventional present value analysis adapted for solar electric power plants by JPL (Ref. 8). It calculates that busbar energy cost in constant-year dollars which will generate system-resultant revenues equal to the system-resultant costs. The inputs for BUSBAR represent two types of information: system cost data and accounting information. The cost data as currently used consist of the arrays of capital costs and O&M costs which are generated in subroutine COST. Escalation rates are input for capital and O&M in addition to the general inflation rate. BUSBAR is written to handle separate maintenance charges, fuel costs and social benefits along with their appropriate rates of escalation. The ECON code also has the capability of doing only the busbar energy calculations if a net present value cost is input.

The second group of input data, the accounting information, represents the variables that are used to determine the cost of capital. From this data, the discount rate, the fixed charge rate, and the capital recovery factor are determined in BUSBAR.

An additional capability exists within ECON for producing plots of the data generated. Subroutine PLOTTT can be called to produce a graph of busbar energy cost versus capacity factor for each system. For the systems which use either thermal or electrical storage, but not both, the graph will have a set of curves, each of which represent a distinct value of collector area with points marked representing various amounts of storage (e.g., Figure 2). For the systems which use both electrical and thermal storage, a separate plot will be generated for each value of collector area. Each plot will consist of a set of curves, each representing an amount of thermal storage with points marked representing amounts of electrical storage.

COMPUTATIONAL TIME

To simulate the annual performance of a point focus central receiver system using 15-minute time steps, approximately 50 seconds of CPU time is required for FIELD and approximately 300 seconds of CPU time for POWER for a full matrix of collector areas and storage sizes for electrical output cases. ECON requires approximately 10 seconds of CPU time in the corresponding simulation.

SUMMARY

A system simulation has been written to model the performance of solar thermal power systems for both electrical and process heat applications. The models are modular allowing for easy use and modification. Annual performance and economics of most proposed solar thermal systems can be modelled by the simulation in its present form.

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Figure 1 - Simplified flow chart for BALDR-1 performance and cost simulation codes

POINT FOCUS CENTRAL RECEIVER-5MWe

Figure 2 - Graphical Output from ECON
Each point marked on a curve represents a different amount of storage.