Performance Assessment Manual

Appendix 2.03 - Detailed Description of Optimization Engine for Performance Analyses

HYDROPOWER ADVANCEMENT PROJECT

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The optimization engine used for the optimization-based performance analyses computes the load allocation among a set of units to maximize overall plant efficiency for a given plant load and head.

The general optimized dispatch problem is represented by the equations below:

maximize $\sum_{i=1}^{N} P_i \quad \sum_{i=1}^{N} \gamma Q_i H_i$ (1)

subject to

$$P_{plant} = \sum_{i=1}^{N} P_i \quad (2)$$

$$P_i \geq Min\ P_i \quad ; i = 1\ to\ N \quad (3)$$

$$P_i \leq Max\ P_i \quad ; i = 1\ to\ N \quad (4)$$

where

P_i = unit power
Q_i = unit volumetric flow rate, function of unit power and unit head
H_i = unit head
γ = specific weight of water
N = number of units on line
P_{plant} = plant power.

This problem is non-linear and non-convex. Because the system of equations is non-convex, the solution for the system will not in general be a global maximum but will depend on the starting solution which is chosen for the system.

The optimization engine uses Solver, available in Microsoft Excel, in conjunction with pre- and post-processing routines. Solver is configured to use a non-linear solver, specifically the generalized reduced gradient algorithm. The pre- and post-processing routines involve a heuristic approach to determine which units to use in producing an optimized solution.

Figure 2.03-1 provides a flow chart outlining the computational approach.

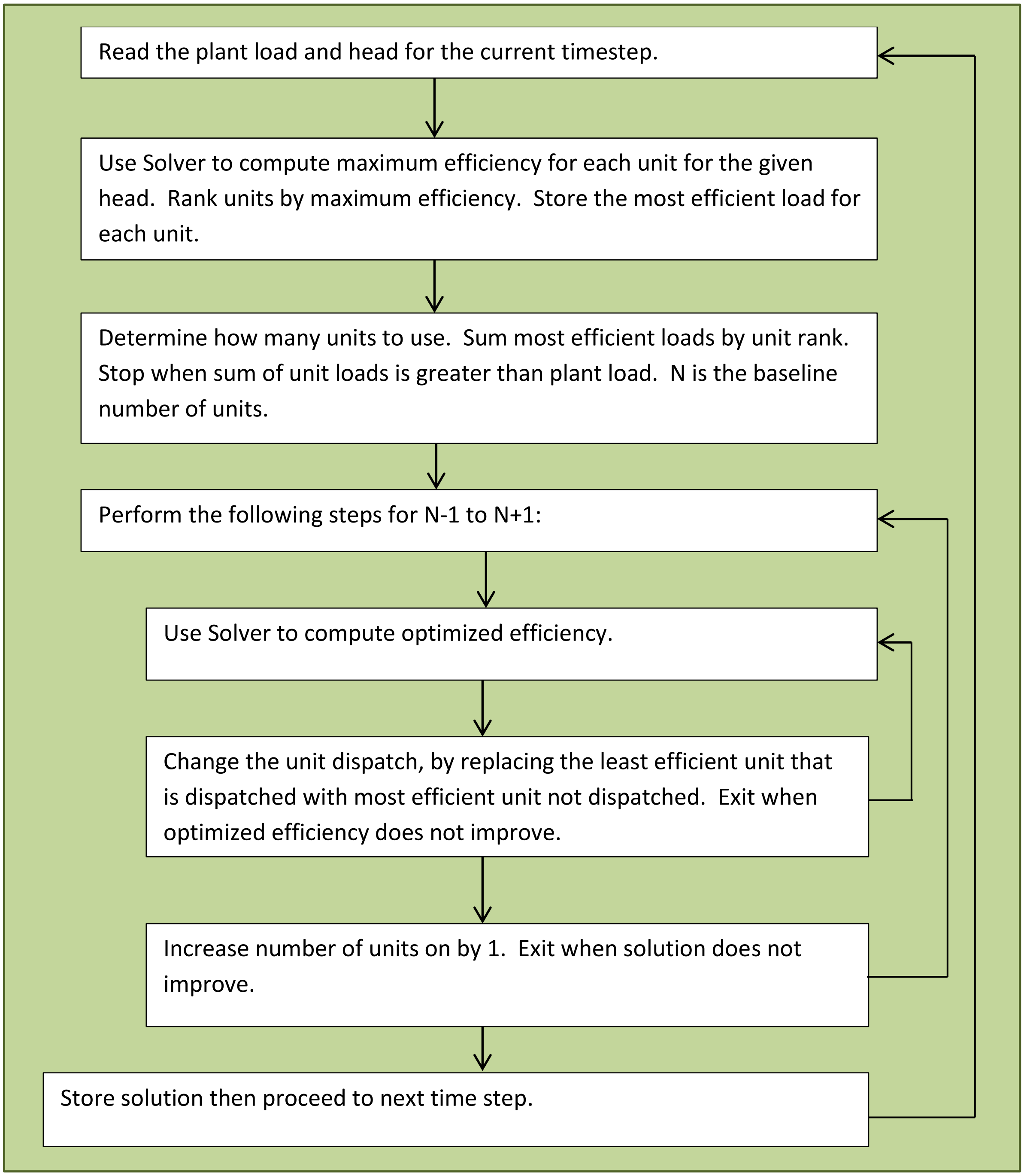

Figure 2.03-1: Steps for the Optimization Calculation

The unit characteristics file that specifies unit flow rate as a function of unit power and head is an important component of this computational approach. Polynomial functions are used to fit the power versus flow data for the purpose of generating a unit characteristics file. Third or fourth order polynomials are usually sufficient to fit the flow data closely.

An example showing a unit characteristics file is provided in Figure 2.03-2.

Unit Indices	1	2	3			
Unit 1						
Head	Min Power	Max Power	C0	C1	C2	C3
800	100.0	386.0	803.4959483	12.95901452	-0.012516449	2.72475E-05
820	100.0	400.0	779.1287276	12.46492887	-0.010171889	2.2593E-05
840	100.0	413.3	762.2243831	12.04814701	-0.008525652	1.92943E-05
860	100.0	426.7	708.8377359	12.26894125	-0.009372311	1.88191E-05
880	100.0	441.2	653.7701053	12.55582708	-0.010748803	1.93791E-05
900	100.0	446.0	602.4557509	12.63716266	-0.011108693	1.89294E-05
920	100.0	446.0	550.7515091	12.74597635	-0.011494927	1.8455E-05
Unit 2						
Head	Min Power	Max Power	C0	C1	C2	C3
800	100.0	384.2	777.0271739	13.34584166	-0.013520041	2.73163E-05
820	100.0	398.2	759.3314157	12.84340597	-0.011366885	2.3142E-05
840	100.0	411.5	733.9298828	12.51138043	-0.010025859	2.02674E-05
860	100.0	424.8	712.3336132	12.08146238	-0.008299093	1.71127E-05
880	100.0	439.3	667.5928913	12.24233532	-0.009288537	1.74768E-05
900	100.0	446.0	603.9127511	12.64118968	-0.011206196	1.90267E-05
920	100.0	446.0	553.1554981	12.62465138	-0.010967545	1.77727E-05
Unit 3						
Head	Min Power	Max Power	C0	C1	C2	C3
800	100.0	376.2	796.2206324	12.59551737	-0.010575133	2.41302E-05
820	100.0	390.0	761.7030756	12.2917749	-0.009040099	2.05049E-05
840	100.0	402.9	723.4770205	12.22593026	-0.008811879	1.89345E-05
860	100.0	416.0	689.245344	12.11197056	-0.008323045	1.70889E-05
880	100.0	430.2	647.2029387	12.04819659	-0.007891678	1.54196E-05
900	100.0	444.5	580.684719	12.52468709	-0.010288174	1.76044E-05
920	100.0	446.0	501.9774617	13.05870716	-0.012634001	1.95113E-05

Figure 2.03-2: Example Showing Unit Characteristics File

For overall questions
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