II.4-RES-SNGL-A-POWERGEN SINGLE RESERVOIR REGULATION OPERATION SCHEME POWER GENERATION

Description

Scheme POWERGEN computes the generation (turbine) outflow (QOM) from a hydroelectric dam.

The generation outflow is affected by the inflow, rule curve elevation (CURVE), maximum generation of this dam (QGENMAX) and downstream dams (DSMAXQ), minimum outflow requirements (MINQINST, MINQDAY, MINQWEEK), diurnal variation of power requirements (DAILY), daily variation of power needs during the week (WEEKLY) and upper (HUPPER) and lower (HLOWER) limiting elevations. The upper limiting elevation must be greater than the rule curve elevation and the lower limiting elevation must be less than the rule curve elevation.

The accuracy of this regulation Scheme increases with the magnitude of inflows. A more accurate Scheme in low flow conditions would require the forecast of future weather conditions and the knowledge of the availability of hydroelectric and other generating capacities throughout the power company service area. This however is beyond our present capabilities.

Although dam operators often adjust the rule curve and POWERGEN provides for using the adjustment computed in the rule curve adjustment Utility (RULEADJ) the RULEADJ Utility should rarely be used for a power dam. Since there is almost always a diurnal and/or weekly variation in power requirements the difference in observed and rule curve elevations would not be representative of the deviation from the rule curve except at specific times. the difference would be representative only when the pool is brought back to the rule curve which is once a day for the daily cycle or once a week for the weekly cycle. RULEADJ is strictly applicable only for power dams that keep the pool elevation constantly at the rule curve elevation until inflow exceeds the maximum generation discharge. Even in this case the FILLSPILL or RULECURVE Scheme would be more appropriate and RULEADJ would be used with one of those Schemes rather than with the POWERGEN Scheme.

If no observed or proposed generation discharge is available outflow must be computed. The computation of outflow in this power generation Scheme requires the execution of the inflow summation Utility (SUMINF) which computes values needed by this Scheme such as cumulative inflow volumes and the existence of a flood situation as determined by the upper limit exceedence criteria in that Utility.

If inflows are large the upper limiting elevation will be equaled or exceeded even with full maximum power generation. Outflow will be set to the maximum generation discharge until the time when the maximum pool storage is exceeded and the inflow recesses below the maximum generation discharge. the daily or weekly cycle power generation operation will then be used.

If inflows are not too large generation outflows are computed by

bringing the pool elevation back to the rule curve either once a day at specified time (TOD) or once a week on a specified day (TOW) and time (TOD). When the pool is brought back to the rule curve once a day the daily outflow volume and the daily mean outflow required to bring the pool from its elevation at the beginning of the daily cycle to the rule curve elevation at the end of the daily cycle are computed. The daily mean outflow is lower limited by MINQDAY and FLOUT and upper limited by QGENMAX. FLOUT is a constant minimum outflow required to keep the pool from exceeding the upper limiting elevation during a forecast run. FLOUT is upper limited by QGENMAX. Both the daily outflow volume and the daily mean outflow will be revised in necessary. If the daily outflow volume is increased or decreased due to the limiting condition of the daily mean outflow the pool cannot be brought back to the rule curve elevation at the end of the daily cycle.

The daily outflow volume is then distributed into time interval mean outflows (QOM) using the daiy distribution fractions (DAILY). The daily distribution ractions are determined from averaging the past generation discharge records. QOM is limited by MINQINST and QGENMAX. When QOM must be changed the excess or the deficit flow volume is distributed first into the remaining time intervals until all QOM have reached their limits before it is carried into the next day.

Then for each daily cycle the pool storage for each time interval is computed and the storage checked against upper and lower limiting storage. Outflows are revised as required to ensure that the pool does not exceed its limits. Excess or deficit flow volumes are carried over to subsequent time intervals. Computation of the outflows will be carried out from day to day until the end of the forecast run.

When the pool is brought back to the rule curve elevation once a week the weekly outflow volume and the weekly mean outflow required to bring the pool from its elevation at the beginning of the weekly cycle to the rule curve elevation at the end of the weekly cycle are computed. The weekly mean outflow is lower limited by MINQWEEK and FLOUT and upper limited by QGENMAX. The upper limit of FLOUT is QGENMAX. Both the weekly outflow volume and the weekly mean outflow will be revised if necessary. If the weekly outflow volume is increased or decreased due to the limiting condition of the weekly mean outflow the pool cannot be brought back to the rule curve elevation at the end of the weekly cycle. The weekly outflow volume is then distributed into the daily flow volumes using the weekly distribution fractions (WEEKLY). The weekly distribution fractions are again determined from averaging the historical release records.

After computing the daily flow volume the outflow as described in the daily cycle is determined. Computation of outflows will be carried out from week to week until the end of the forecast run.

Unless the program is in another Scheme this power generation Scheme will be executed every time interval throughout the forecast run. The generation outflow might be observed, proposed by the dam operator or computed from the daily or weekly cycles described above.

Once the outflow is known the beginning pool storage for the time interval and mean inflow and outflow are used in the continuity equation to compute the pool storage and elevation at the end of the time interval.

If the outflow is observed it is plugged directly into the continuity equation to compute the pool storage and the pool elevation. Pool storage is in units of mean discharge for a time interval.

$Q0_2$ = QOM
$V_2 = V_1 + QIM - QOM$
$H_2 = h(V_2)$

where H is h(V) - the elevation versus storage curve for the reservoir

If the outflow is proposed by the operator it is treated in the same way as observed except checking against limiting values is made and pertinent values are revised if needed.

First check against upper limit:

$V_2 = MIN (V_2, STORUP)$ where STORUP = v(UPPER)

$QOM = V_1 + QIM - V_2$
$QOM = MIN (QOM, QGENMAX)$

Then check against the lower limit:

$V_2 = MAX (V_2, STORLR)$ where STORLR = v(LOWER)

$QOM = V1 + QIM - V_2$
$QOM = MAX (QOM, MINQINST)$

Plug QOM into the continuity equation to compute the pool storage and the pool elevation.

QO_2 = QOM
$V_2 = V_1 + QIM - QOM$
$H_2 = h(V_2)$

Although a single value of maximum generation discharge is usually satisfactory more accurate values can be determined with a pool elevation maximum turbine discharge relation if there are extreme variations in head. However data for developing this relation is rarely available from regulation manuals and therefore the single value would generally be used. The pool elevation versus maximum generation discharge relation is applicable only if there is no appreciable spillway and/or sluice discharge.

If maximum generation discharge varies with elevation the initial specified constant QGENMAX is used to estimate the initial outflow time series. The maximum generation discharge is then determined from the elevation maximum generation discharge relation as a final check after pool storage is computed from the initially estimated outflow. If greater than the maximum value the outflow is reduced to

the computed maximum generation discharge and a revised storage is computed. It was considered that this procedure is sufficiently accurate and is much less cumbersome than computing storages and elevations and the maximum generation discharge simultaneously for each time interval.

If the outflow needs to be computed it is determined in such a way that the pool elevation will be brought back to the rule curve elevation on a daily or weekly basis while not to exceed their limiting values. To ensure that upper limit will not be exceeded, a maximum constant flow (FLOUT) that allows the pool to reach its upper limit at time interval (NP) is determined iteratively from the following equations:

$$STORUP = S_o + \sum_{IT=JBGN}^{NP} QIM - NP * FLOUT$$

where S_o is the pool storage at IT=JBGN

FLOUT is limited between $0 \leq FLOUT \leq QGENMAX$

FLOUT has two functions. First FLOUT serves as a lower limit to the daily mean outflow and the weekly mean outflow to keep the pool from exceeding the upper limit. Second if downstream dam limiting discharge (DSMAXQ) is not equal to QGENMAX and DSMAXQ < FLOUT < QGENMAX then FLOUT is used to determine the switching point from DSMAXQ to QGENMAX to save water as well as to keep the pool from exceeding the upper limit.

If the upper limit will be equaled or exceeded with full generation during a forecast run then reservoir release will be set to the maximum generation discharge until pool has exceeded its upper limit and inflow starts to recess to below the maximum generation discharge. The time interval NEMXST for pool to reach its upper limit is determined from:

$$NEMXST = \left(S_o + \sum_{IT=JBGN}^{NEMXST} QIM - STORUP \right) / QGENMAX$$

where JBGN = MAX (LOBSTO, LPROP) + 1

S_o is the storage at IT=JBGN

QOM(IT) = QGENMAX if $IT \leq NEMXST$

QOM(IT) = QGENMAX if $IT > NEMXST$ and $QIM(IT) \geq QGENMAX$

Maximum pool storage can occur at a later time interval than NEMXST and can be greater than the upper storage limit. If IT > NEMXST and QIM(IT) < QGENMAX then the operation switches to the daily or weekly operation cycle.

If the maximum generation discharge will keep the pool from exceeding its upper limit during a forecast run then outflow can be computed

from either daily or weekly operation cycle.

Daily Cycle

For a daily cycle the pool will be brought back to the rule curve elevation daily. Computation of outflow is carried out by first computing the daily release volume then distributing that volume over every time interval using the inputted daily distribution function. During any day of the forecast run the total daily release volume is determined as follows:

$$VOLD' = SD_o + \sum_{1}^{NTIM24} QIM - RULSTO$$

where SD_o is the pool storage at the beginning of the daily cycle

RULSTO is v(RULE) - the pool storage at the end of the daily cycle corresponding to the pertinent rule curve elevation

NTIM24 is the number of computational time intervals in a daily cycle

Since maximum daily release volume equals QGENMAX * NTIM24 then:

VOLD' = MIN (VOLD', QGENMAX * NTIM24)

If QGENMAX ≠ DSMAXQ and DSMAXQ < FLOUT < QGENMAX then use DSMAXQ for outflow until time interval NCHANG (rounded off to its nearest whole day) when outflow must be changed to QGENMAX to keep the pool from exceeding the upper limit at time interval, NP. NCHANG is determined by equating outflow volume from DSMAXQ and QGENMAX to FLOUT as follows:

FLOUT * (NP - JBGN + 1) = DSMAXQ * (NCHANG - JBGN + 1) + QGENMAX * (NP - NCHANG)

where JBGN is the time interval number when the daily cycle computation begins

Solve for NCHANG then:

NCHANG = {[(NP - JBGN + 1) * FLOUT] + (JBGN * DSMAXQ) - DSMAXQ - (NP * QGENMAX)} / (DSMAXQ - QGENMAX)

Daily release volume is set as follows:

VOLD' = DSMAXQ * NTIM24 if IT < NCHANG

VOLD = QGENMAX * NTIM24 if NCHANG < IT <_NUM then round off NCHANG to the nearest whole day

Daily mean outflow is determined from:

QOMD' = VOLD'/NTIM24

The daily mean outflow is subject to the following limits and will be

revised if necessary:

QOMD = MAX (QOMD', MINQDAY, FLOUT, 0)

The allowable daily release volume is then revised to

VOLD = QOMD * NTIM24

Since VOLD $\geq$ VOLD' the pool may not be brought back to the rule curve by the end of the daily cycle.

The 24-hour mean daily outflows into time interval mean outflows are then converted into time interval mean outflows:

VOLD = QOMD * NTIM24

QOM = VOLD * DAILY

QOM is limited by QGENMAX and MINQINST:

QOM = MIN (QOM, QGENMAX)
QOM = MAX (QOM, QMININST)

Then the upper and lower limiting storage is checked. The outflows are changed to keep from exceeding the upper storage or dropping below the lower storage.

$V_2 = V_1 + QIM - QOM$

If STORLR < V_2 < STORUP for all time intervals no change is required. Advance to the next day for a new daily cycle of QOM computation.

If V_2 > STORUP then revise V_2 and QOM as follows:

V_2 = STORUP and
QOM = V_1 + QIM - STORUP
QOM = MIN (QOM, QGENMAX)

The excess flow over QGENMAX will first be distributed into the rest of the time intervals with QOM < QGENMAX. If QOM for all the time intervals has reached QGENMAX then the excess flow will be carried forward into the next day.

If V_2 < STORLR then revise V_2 and QOM as follows:

V_2 = STORLR and
QOM = V_1 + QIM - STORLR
QOM = MAX (QOM, QMININST)

The deficit flow under MINQINST will first be made up from the rest of the time intervals with QOM > QMINST. If QOM for all the time intervals is equal to MINQINST then the deficit flow will come from the next day's release.

A total of NTIM24 values of QOM are generated for a whole daily cycle. Computation of outflow will be carried out on a day-to-day

basis until the last time interval of the forecast run is reached.

Weekly Cycle

For a weekly cycle the pool will be brought back to the rule curve elevation weekly. Weekly release volume is computed and distributed into daily release volumes using a specified weekly distribution function. The daily release volume is then distributed using the specified daily distribution function to obtain the time interval outflow.

The total weekly release volume is determined as follows:

$$VOLW' = SW_o + \sum_{1}^{7*NTIM24} QIM - RULSTO$$

where SW_o is the pool storage at the beginning of the weekly cycle

RULSTO is V(RULE) - the pool storage at the end of the weekly cycle corresponding to the pertinent rule curve elevation

Since maximum weekly release volume equals to QGENMAX * 7 * NTIM24 then:

VOLW' = MIN (VOLW',QGENMAX * 7 * NTIM24)

If QGENMAX $\neq$ DSMAXQ and DSMAXQ < QGENMAX the total weekly release volume is determined from:

VOLW' = DSMAXQ * 7 * NTIM24 if IT < NCHANG

VOLW' = QGENMAX * 7 * NTIM24 if NCHANG < IT < NUM round off NCHANG to the nearest whole day

Weekly mean outflow is determined from:

QOMW' = VOLW'/(7 * NTIM24)

The weekly mean outflow is subject to the following limits and will be revised if necessary:

QOMW = MAX (QOMW', MINQWEEK, FLOUT, 0.)

The allowable weekly release volume is then:

VOLW = QOMW * 7 * NTIM24

Again since VOLW $\geq$ VOLW' the pool may not be brought back to the rule curve by the end of the weekly cycle. The weekly release volume is then distributed using the weekly distribution function to obtain daily release volumes for each day of the week:

VOLD = VOLW * WEEKLY

When VOLD is less than the volume of MINQDAY (or MINQINST) * NTIME24

for one or more days then the sum of the excesses of MINQDAY (or MINQINST) * NTIM24 over VOLD will be subtracted in equal increments from the values of VOLD for the remaining days of the weekly cycle.

Daily mean outflow is computed and checked against appropriate limits and revised if necessary:

QOMD = VOLD/NTIM24

QOMD = MAX (QOMD, MINQDAY, MINQINST)

Then the time interval outflow is computed and checked against pertinent limits as given in the daily cycle.

A total of 7 * NTIM24 values of QOM are generated for a whole weekly cycle. Computation of outflow will be carried out from day to day within the weekly cycle. Then advance to the following week and carry out computation from week to week until the last time interval of the forecast run is reached.

Now that QOM values have been established they are plugged into the continuity equation to compute the pool storage and the pool elevation as if they were proposed data:

$QO_2 = Q0M$
$V_2 = V_1 + QIM - QOM$
$H_2 = h(V_2)$