Operating algorithm of hybrid power plant of a wind park and a Pumped Hydro Storage system for power peak shaving

In cases of large power systems, a hybrid station is usually introduced for power peak shaving. The operation under the above presented algorithm, aiming at the RES penetration maximization in the power system, is not impossible in cases of large power systems. However such a perspective requires technical works and infrastructure of large scale which, respectively, impose high set-up cost. Consequently, the introduction of hybrid power plants for power peak shaving constitutes a more conservative option.

The operation algorithm for a power peak shaving wind powered PHS is presented below. The fundamental control, which comes first and determines the hybrid station operation mode, is whether the current calculation time step is included among the power demand peak daily period or not. The following cases are distinguished:

A. Power demand peak daily period (guaranteed power production period):

1. During the power demand peak periods the hybrid power plant must have adequate energy storage to provide the pre-defined guaranteed power production for the pre-defined time periods. From the previous day, the available energy storage is evaluated and the guaranteed energy production is determined for the next day.
2. The power production from the RES unit P_{RES} and the pre-defined guaranteed power production P_g are introduced. Additionally, a maximum RES direct penetration percentage versus the guaranteed power production p_{max} is defined.
3. The direct RES penetration P_{RESp} versus the guaranteed power production from the hybrid power plant is calculated as presented below:
   i. If $P_{RES} \geq p_{max} \cdot P_g$, then $P_{RESp} = p_{max} \cdot P_g$.
   ii. If $P_{RES} < p_{max} \cdot P_g$, then $P_{RESp} = P_{RES}$.

4. The required guaranteed power production from the storage unit is then calculated:

   $P_h = P_g - P_{RESp}$.

5. The water volume V_h that must be removed from the PHS upper reservoir to achieve a hydro turbines power production of $P_g – P_{RESp}$ for a time calculation step of duration t is calculated:

   $V_h = (P_d – P_{RESp})\cdot t / \eta_h \cdot \gamma \cdot H_T$.

B. During the whole daily period:

6. If P_p is the nominal power of the storage units (pumps), then the potential power storage P_{st} is calculated as follows:

   a. If $P_{RES} – P_{RESp} > P_p$, then $P_{st} = P_p$.
   b. If $P_{RES} – P_{RESp} \leq P_p$, then $P_{st} = P_{RES} – P_{RESp}$.

7. The water volume V_p that must be stored in the PHS upper reservoir to achieve power storage P_{st} for a time calculation step with duration t is calculated:

   $V_p = P_{st}\cdot t \cdot \eta_p / \gamma \cdot H_P$.

8. The water volume $V_{st}(j)$ remaining in the PHS upper reservoir after the current calculation time step j is calculated as:

   $V_{st}(j) = V_{st}(j-1) + V_p – V_h$

9. The capacity V_{max} of the PHS upper reservoir to store the potential water volume remaining after the current time calculation step is examined:

   a. If $V_{st}(j) > V_{max}$, then:
      $P_{st} = 0$
      $P_{rej} = P_{RES} – P_{RESp}$
      $V_{st}(j) = V_{st}(j-1) – V_h$.

   b. If $V_{st}(j) \leq V_{max}$, then:
      $P_{st} = P_p$ or $P_{st} = P_{RES} – P_{RESp}$.
      $P_{rej} = P_{RES} – P_{RESp} – P_{st}$
      $V_{st}(j) = V_{st}(j-1) + V_p – V_h$.

To approach both the above described operation algorithms the simultaneous power production and storage is required. To meet this option, the installation of a double penstock is necessary. The introduction of a double penstock maximizes the operation flexibility of the hybrid power plant, increases the annual RES penetration approximately up to 20% and significantly contributes to the dynamic security of the power system.