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Cluster auto control

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Azelio cluster auto control

TES.PODs can be grouped in clusters of up to 40 units, which are managed by a common cluster control system in the SSC (Storage System Controller). How the SSC manages the TES.PODs in the cluster has a significant impact on the operation of individual TES.PODs and on the dynamic behaviour within the hybrid energy park. This paper outlines the key principles of the cluster control.

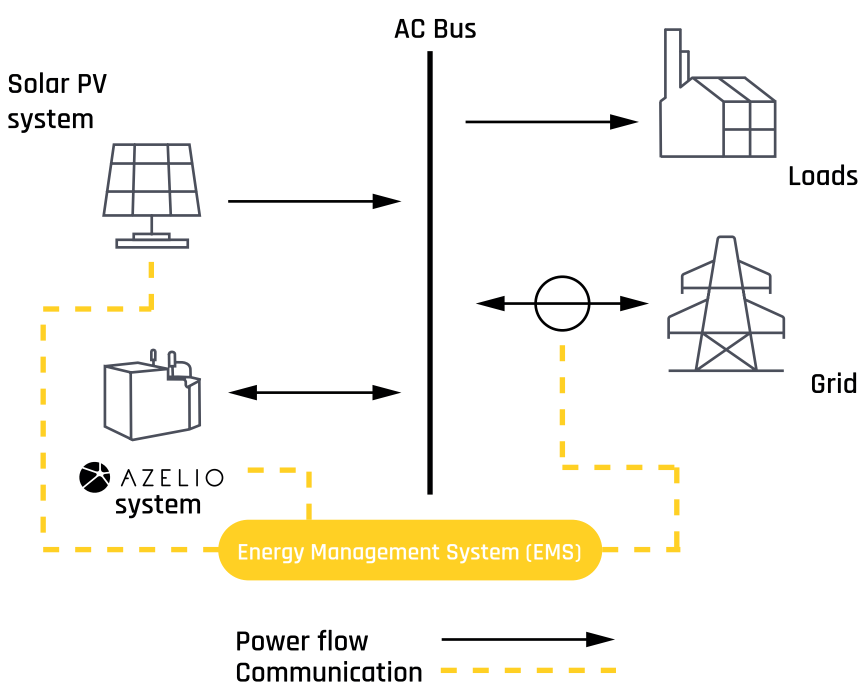
INTRODUCTION

The cluster is typically one of several systems present in a complete hybrid energy park, figure 1. The Energy Management System (EMS) controls the different systems in the park to e.g., fulfil the load demand as best possible, minimise curtailment and minimise grid imports.

The EMS gives commands to the SSC for the cluster's required total charge and discharge power. How the cluster control is configured has a significant impact on the operation of each TES.POD on cluster performance, and how an energy park dynamically experiences the total instantaneous power flow from the cluster.

The SSC decides which TES.POD should operate, and at what power level, in order for the cluster to fulfil the total power request received from the EMS, whether for charge or discharge. The same total power yield can be achieved by several possible combinations of either few TES.PODs at high power levels or by many at low power levels.

Figure 1 Hybrid energy park



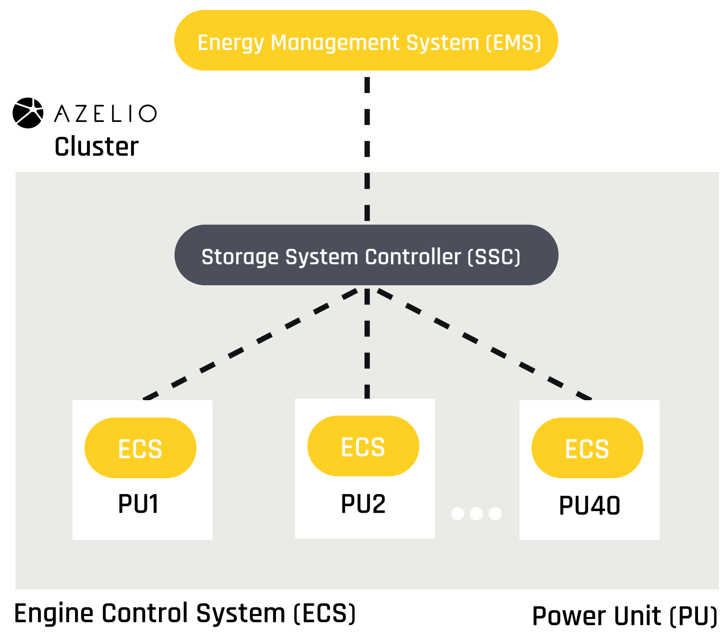
SYSTEM HIERARCHY

The Azelio system is organised as follows. The EMS controls one or more TES.POD clusters.

Each cluster has a Storage System Controller (SSC) system that manages one or more TES.POD units, figure 2.

Each TES.POD is autonomous with regard to its individual operation. This means that the unit only needs the power setpoint from the upstream control system, and it will decide operating point by itself to reach that power setpoint.

Figure 2 TES.POD system hierarchy



The task of the SSC is to split the power requests from the EMS and distribute individual setpoints to each unit. The split between each unit does not need to be uniform but considers the current conditions of each individual TES.POD unit and splits the upstream power request accordingly.

Each TES.POD unit will independently decide its own suitable operating speed and working pressure for its Stirling engine, based on its individual conditions to match the discharge power setpoint from the SSC. It is thus possible that two TES.POD units in the same cluster might deliver the same power but run their Stirling engines at different operating points.

In order for the SSC to be able to individually tailor the power setpoints, each unit communicates its operating limits upstream.

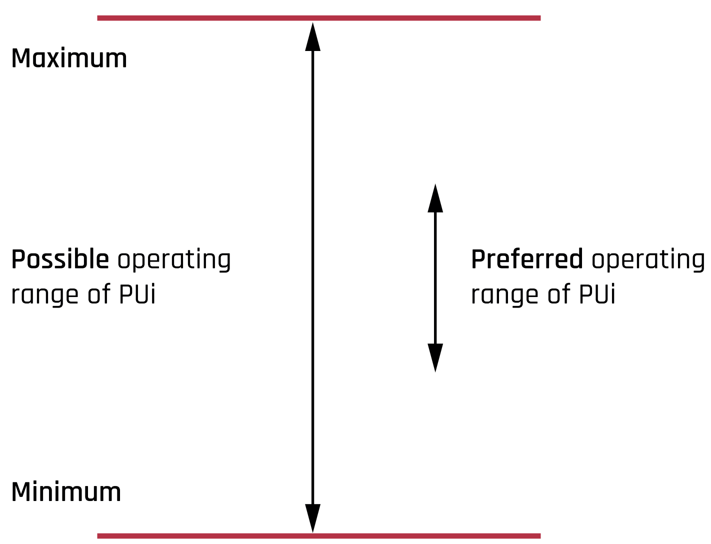
KEY PRINCIPLES

There are some key principles upon which the control logic is built. A few of these will be discussed here.

Before starting the units, the adequate storage capacity available to start must be checked and also an estimate made of time for continuous operation. In addition, it is desirable to balance running time between units to achieve similar wear. More specifically, a compound service score is calculated based on running time and load point so that the units with lowest score are ranked to start first.

The TES.POD unit shall, as much as possible, operate in the preferred operating range rather than in the possible range, figure 3, for reasons of efficiency, wear, power reserve, power ramp rate and adequate control range. This is true both for charge and discharge operation. The preferred operating range also directly determines the resulting number of operating TES.PODs in the cluster for a specific total power request from the EMS.

Figure 3 Possible and preferred operating ranges



By allowing temporary operation outside the preferred range, an increased ramp-rate capacity can be achieved, without having to start additional TES.PODs.

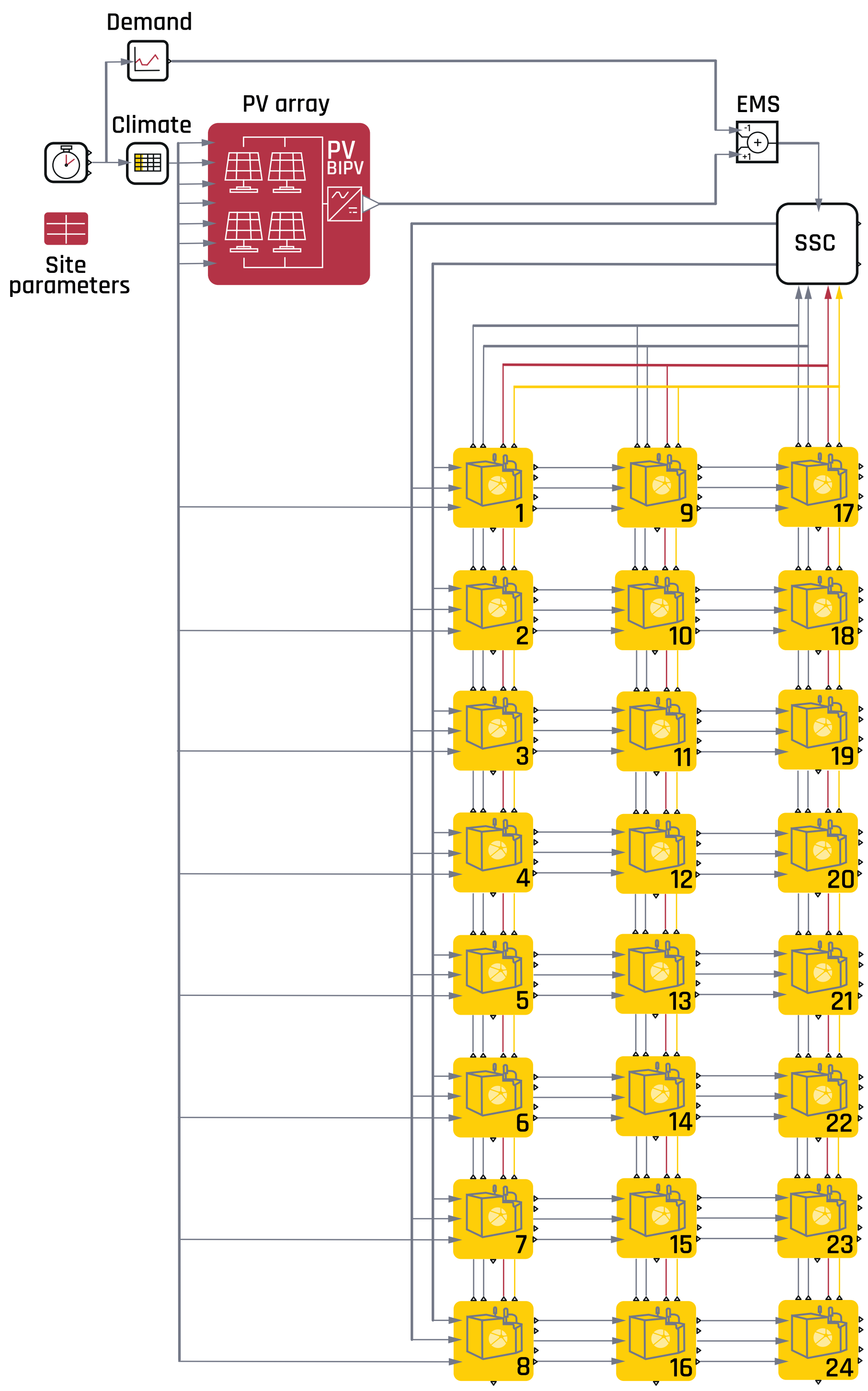
Having sufficient room for power ramp-up and ramp-down is important, especially in installations where the EMS power setpoint sees large fluctuations.

Finally, the cluster is operated to minimise any disturbances to the grid stability or power quality.

VIRTUAL DEVELOPMENT

The control algorithms are developed and tested in Azelio's virtual system laboratory. Figure 4 shows an example of a micro-grid with a solar panel array and a TES.POD cluster of 24 units.

Figure 4 Virtual laboratory model with PV array (red) and TES.PODs (yellow)



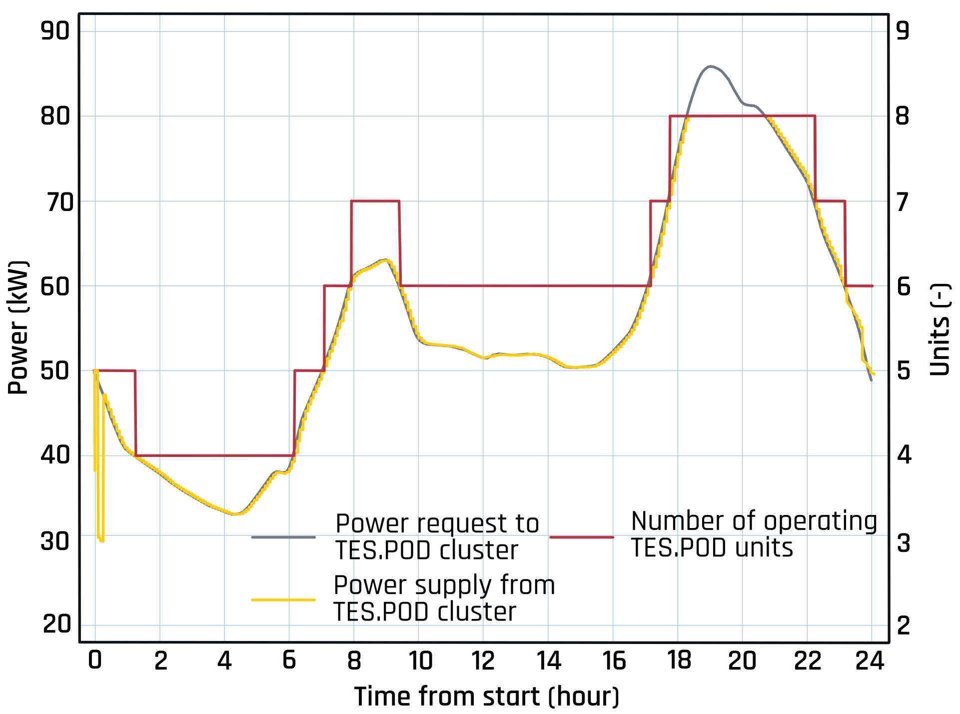
LOAD FOLLOWING CHARACTERISTICS

The SSC continuously monitors the power requests from the EMS and responds to variations by starting and stopping units to provide the right number of operating TES.POD units at any given time. In addition, it modulates the power of individual units based on the power ramp times of operating TES.POD units to provide a load-following capacity.

The EMS can utilise the cluster to minimise curtailment by monitoring excess solar PV generation and request a charging power to the SSC accordingly. The corresponding discharging power from the cluster can be utilised by the EMS to e.g., reduce the grid import accordingly.

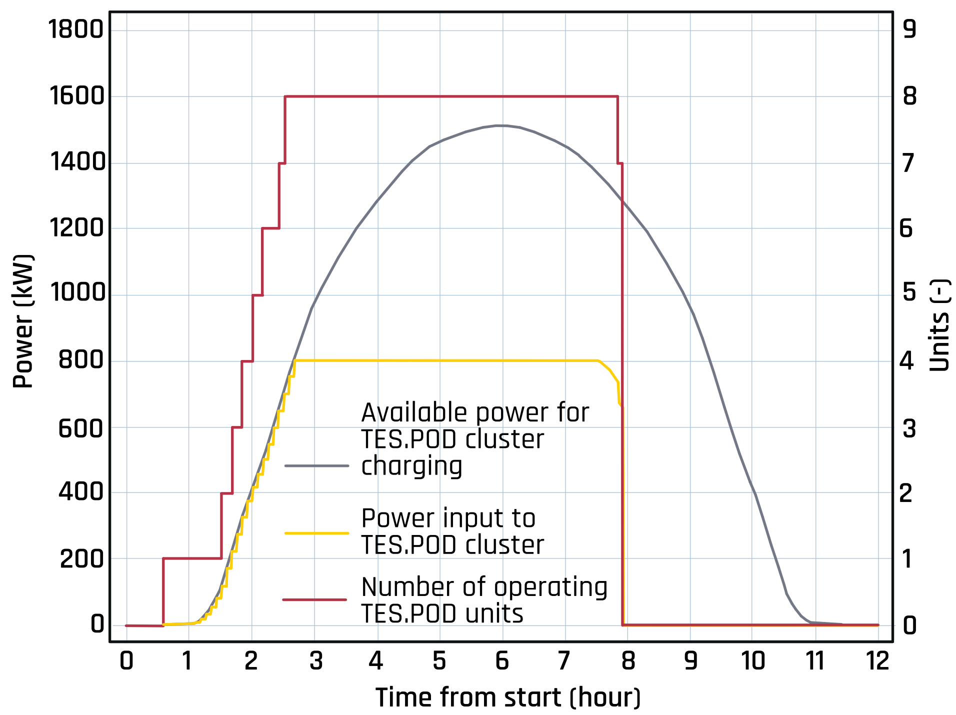
Figures 5 and 6 show how an 8-unit cluster would operate in discharge and charge operation respectively. The change in number of operating units is clearly shown in Figure 5, as is the excellent load following capability for much of the discharge duration. The load following capabilities of each single TES.POD unit ensure that the power request is fulfilled at any point in time. The duration of the discharge is very long due to operation at mostly partial load. In this case, the maximum net discharge power was set to 10 kW per unit, which is reached between the 18th and the 21st hour from the start of discharge.

Figure 5 Load following during discharge



Load following during the charge phase is shown in Figure 6. Assuming a typical solar PV array power profile, the charging power quickly ramps up to a maximum of 100 kW per unit, which applies to the number of units being charged. The available power is larger than 800 kW (8 units x 100 kW each), so the charging process is completed after circa 8 hours from the start of the charge phase.

Figure 6 Load following during charge



CONCLUSIONS

A complete cluster control system has been developed to control up to 40 TES.POD units with the objective of following the charge and discharge load profiles. The autonomous control system monitors the state of each TES.POD and engages units best suited to deliver power to the demand. This logic is based on several operational parameters, such as state of charge and historical operational data. The control logic has been simulated in an in-house developed software. It has been shown that the system can follow demand profiles, both in charge and discharge mode.