Case Study 4: 6 kW WECS Optimal Control by PI Power control

This case study contains an application implementing the WECS optimal control using a PI-based electrical (active) power control loop. This application uses the mdl-file named `PI_power_ctrl.mdl` and is described below.

Scope: Evaluation by numerical simulation of the control method aiming at power maximization for a low-power fixed-pitch SCIG-based wind turbine by tracking the optimal power value issued from the $K \cdot \Omega^3$ relation (Relation 4.4 in the book). The outer control is an active power loop; its reference is computed using the rotational speed measurement, the optimal tip speed ratio and the maximum aerodynamic efficiency; the error is zeroed using a PI controller.

Application analysis: The file `data_PIpower.m` contains the system data. The mdl-file is organized as follows. At the right is placed the plant (also containing the inner torque control loop), whereas at the left one can see some blocks (from up to down): the system data loading button, the scopes and some computation/display blocks (containing, for example, the active power calculation), some conditioning operations and the outer control loop implementing the active power control algorithm (bottom-left). The SCIG model is coded in the `asmcn.m` s-function; a pre-computed wind speed sequence can be found in `vntu.mat` file.

One can use multiple wind velocity sequences/profiles for testing the controlled system behaviour, selectable from the wind speed generator. The interaction regime between the WECS and the electrical grid cannot be changed. The WECS implementation comprises the turbine, the rigid drive train, the induction machine and the generator-side inverter. The electrical grid has been taken as ideal, as the grid interface is not of interest in this application. The PI control parameters, T_i and K_p (which can be found in the block labeled `PI Power Control`), are the adjusting elements of the control law. The associated diagram uses the fact that the values of active power and electromagnetic torque of the asynchronous machine are negative in generator regime. The compensation of the plant zero is achieved by using a filter on the controller output.

Running the application:

Step 1: Load system parameters.

Step 2: Select the wind velocity sequence according to your test needs.

Step 3: Select from the menu “Simulation → Parameters” a convenient time horizon and proceed with the simulation.

Step 4: Dynamical system behaviour can be overviewed by opening the scopes (left-upper part of the application file). Operating point position and/or its variation around the ORC can be plotted using the LSS mechanical power and rotational speed data (vectors `pwrl` and `omgl`) saved in the workspace from the associated scopes. The histograms of the power error (and of the tip speed ratio also) can be plotted using the following procedure:

```
err=pwr_err(1000:length(pwr_err),2);    % uses the power error sequence data
                                        % stored by the associated scope
[hst,ics]=hist(err,100);                % histogram with 100 bins
plot(ics,hst/length(err),'k');          % normalisation
```

Step 5: Change the K_p control parameter (in the outer control block) and restart the simulation.

Remarks: During its start-up the system works at zero electromagnetic torque; after few moments, when the rotational speed reaches a normal operating value, the reference automatically switches to the one issued from the PI speed control algorithm. The start-up strategy can be changed by the user, if needed. The identification of the plant behaviour (the T_z value) can be done by switching the electromagnetic torque control input between two constant values – see the block labelled `Enable References`. The system has to be in steady-state, in a normal operating point, under a constant wind velocity. The active power response gives the requested information.