Case Study 8: QFT Robust Control

This case study contains an application implementing the QFT robust control which aims at maximizing the energy extraction for a PMSG-based WECS. The control structure contains two separate controllers, C_1 and C_2, developed by applying the QFT method on the concerned WECS operating in two wind velocity ranges: 3–9 m/s and 5–11 m/s respectively. This application uses the mdl-file named `robust_QFT_ctrl.mdl`; it is described below.

Scope: Evaluation by numerical simulation of the control method aiming at maximizing the captured power for a low-power fixed-pitch PMSG-based wind turbine by using a control structure designed using the QFT method. As the system is nonlinear, variant, presents quasi-unknown dynamics and is subject to unknown disturbances, this method can be the key to obtain a robust controller for driving the WECS to its optimal energy regime in the partial-load operation. Two controllers (each containing a prefilter and a compensator) have been developed using the QFT Toolbox from MATLAB®. The two controllers are embedded in a multi-model control structure.

Application analysis: The file `data_robust_QFT.m` contains the system data. The parameters concerning the system modelling as well as the QFT controller transfer functions are given here. The mdl-file is organized as follows. The plant is placed central-upper, the controller block is at the bottom of the diagram. The wind velocity synthesizer, placed in the upper-left corner, allows using a pre-computed non-stationary wind speed sequence (selection 4) for feeding the WECS; other sequences (including constant wind) are also available. In the bottom-left corner one can see some blocks (from up to down): the system data loading button, the scopes and some computation/display blocks.

The plant is modelled using the simplified aerodynamic model (which provides the wind torque), the motion equation of the rigid drive train and the *d*-*q* modelling of the PMSG (providing i_d , i_q and the electromagnetic torque).

The controller is structured as follows. The wind velocity and the rotational speed feed the two controllers. Their output is weighted by a weighting generator. The weights are obtained based on the low-frequency component of the wind speed. These weights are complementary, as the two controllers are designed for different wind velocity ranges. A filter cancelling the turbulence component can be employed in obtaining the weights.

Running the application:

Step 1: Load system parameters.

Step 2: Select from the menu “Simulation → Parameters” a convenient time horizon and proceed with the simulation.

Step 3: The switch feeding the control input in the block entitled `QFT control` must be set on the “multi-model controller” position.

Step 4: Select the pre-computed sequence of wind speed (selection 4).

Step 5: Dynamical system behaviour can be viewed by opening the scopes (upper-left corner of the application file). Operating point position or its standard deviation 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. Check the control performance by opening the power coefficient (`cp`) and the tip speed (`lam`) scopes, also. The control components, corresponding to the two controllers in the multi-model design structure, are c_1 and c_2. The histograms of the tip speed ratio for several values of the wind filter cut-of frequency (from 5 s to 25 s) can be plotted using the following commands:

```
lam1=lam(1000:length(lam),2);     % uses the tip speed sequence data stored on
                                  % the associated scope
[hst,ics]=hist(lam1,100);         % histogram with 100 bins
plot(ics,hst/length(lam1),'k');   % normalisation
```

Step 6: Change the wind velocity to constant value (selection 1) and change the wind mean value in steps of 1 m/s. The system dynamic behaviour can be seen on the HSS rotational speed (omgh) scope; the disturbance rejection can be assessed on the tip speed ratio or the power coefficient scopes. The electromagnetic torque evolutions (emT), showing the dynamic response deterioration, can be viewed on the corresponding scope.

Step 7: Set the switch feeding the control input in the block named QFT control on the "QFT controller" position.

Step 8: Repeat *Steps* from 4 to 6 to assess the QFT-controlled WECS dynamic behaviour and controller performance.

Remarks: The PMSG is considered to be voltage-controlled by a rectifier-chopper pair, whose influence on the PMSG can be assessed through the equivalent resistance experienced by the generator. In the diagram Rch plays the role of R_S from the textbook.

The user can develop other controller(s) by following the design procedure given in Appendix B.3 from the textbook.