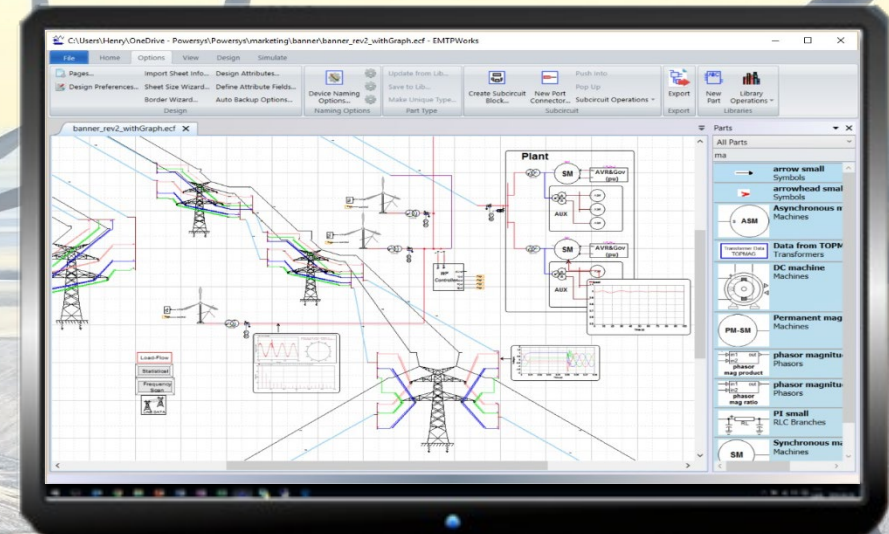


Automatic model parameter determination to fit IBR behavior.

Willy Nzale, *EMTP*
Victor Velar, *COORDINADOR*



EMTP



More info

www.EMTP.com

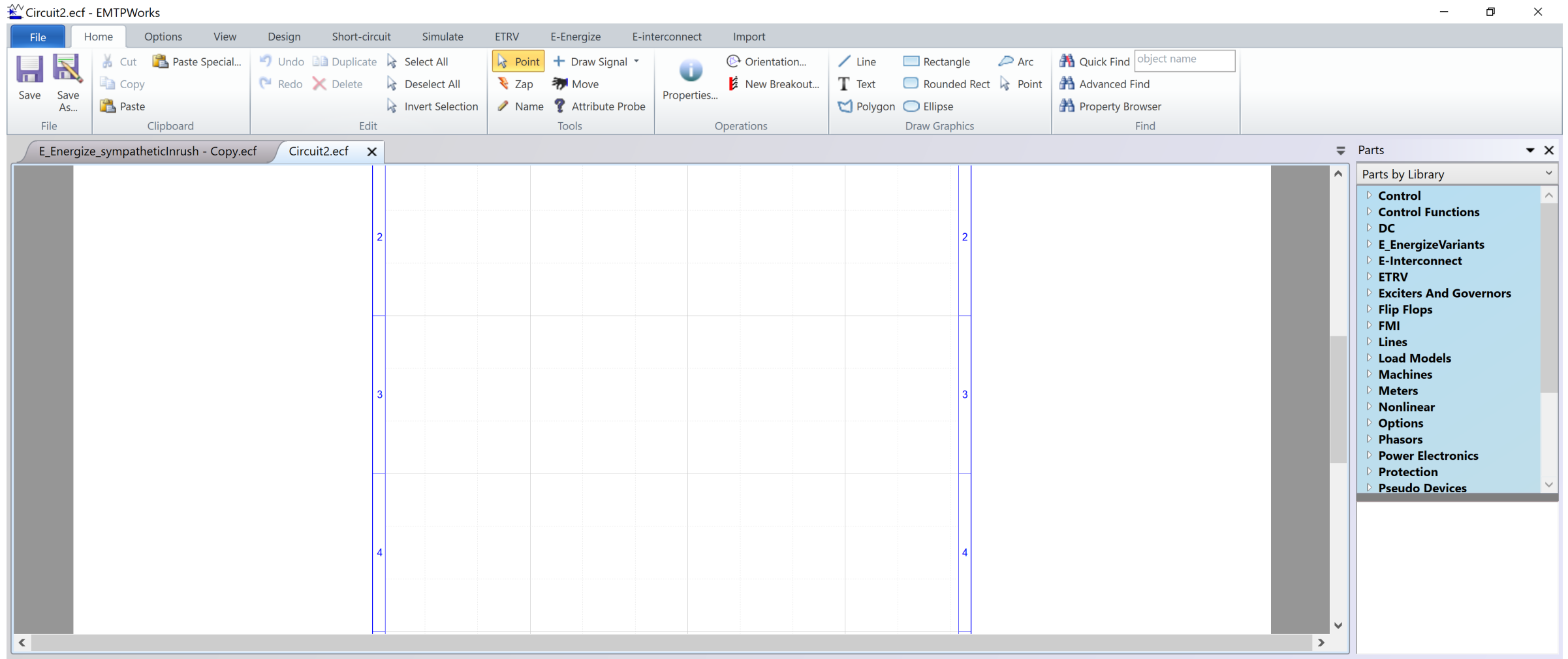
info@emtp.com

Content

- I. Tool development capability of EMTP
- II. Automatic model parameter determination
- III. The IBR data fit tool
- IV. Case study
- V. Conclusions

I. Tool development capability of EMTP

I. Tool development capability of EMTP



I. Tool development capability of EMTP

C:\Willy_Nzale\PGSTech\Henry\Project_IBR_Data_Fit\Mes_tests\testcircuit9\..._Benchmark_PV_example.ecf - EMTWork

The screenshot displays the EMTWork software interface for a project titled "Benchmark_PV_example.ecf". The main window is divided into several panels:

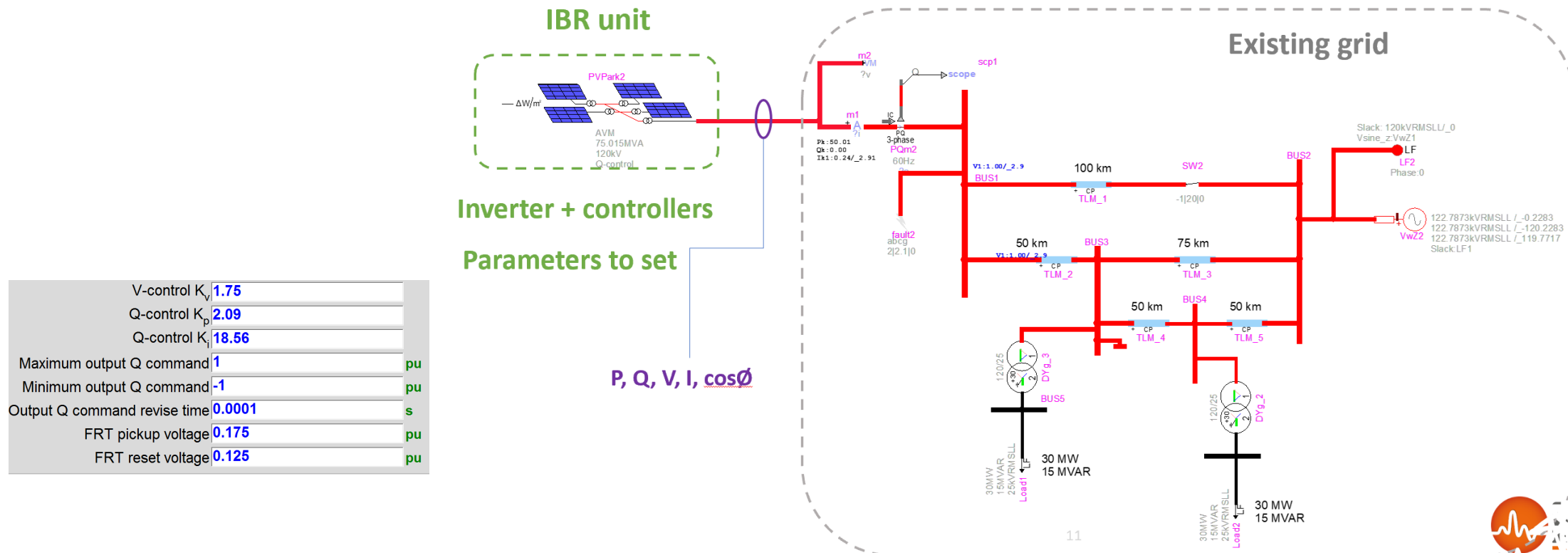
- File Menu:** Includes options like "Open IBR_data_fit interface", "Open IBR_data_fit documentation", and "Open IBR_data_fit".
- IBR_data_fit panel:**
 - Steps:** Step 1: Select parameters; Step 2: Simulation data definition; Step 3: Optimisation definition (selected).
 - Optimisation definition:** Select the optimisation method (PSO). Set parameters for Particle Swarm Optimisation (PSO) method:
 - Number of particles: 5
 - Inertia coefficient (w): 1
 - Inertia Weight Damping Ratio (kappa): 0.99
 - Personal acceleration coefficient (c1): 2.0
 - Social acceleration coefficient (c2): 2.0
 - Maximum number of iterations: 10
 - Cost function type: Sum Absolute Error
 - Convergence tolerance: 1 %
 - Buttons: "Save data", "IBR Data Fit", "MPLLOT", "IBR_data_fit_Meas_Data", "Reference signal".
- IBR data fit version:** 1.0
- Main Circuit Diagram:** Shows a PV Park (PVPark1) connected to a bus (BUS1) via a 3-phase PQM1 inverter. Parameters include V_PPC (7V), I_park (50.01), and a fault (fault1) applied to phase abcg. A scope (IBR_data_fit_Si) is connected to the output.
- Parts by Library:** A list of components including Control, DC, E-Interconnect, ETRV, Exciters And Governors, Flip Flops, FMI, IBR_data_fit, Lines, Load Models, Machines, Meters, Nonlinear, Options, Parameter Sweep, Phasors, Power Electronics, Protection, Pseudo Devices, Renewables, RLC Branches, SimulinkDLL, Sources, Switches, Symbols, Transformations, and Transformers.

II. Automatic model parameter determination

II. Automatic model parameter determination

Context:

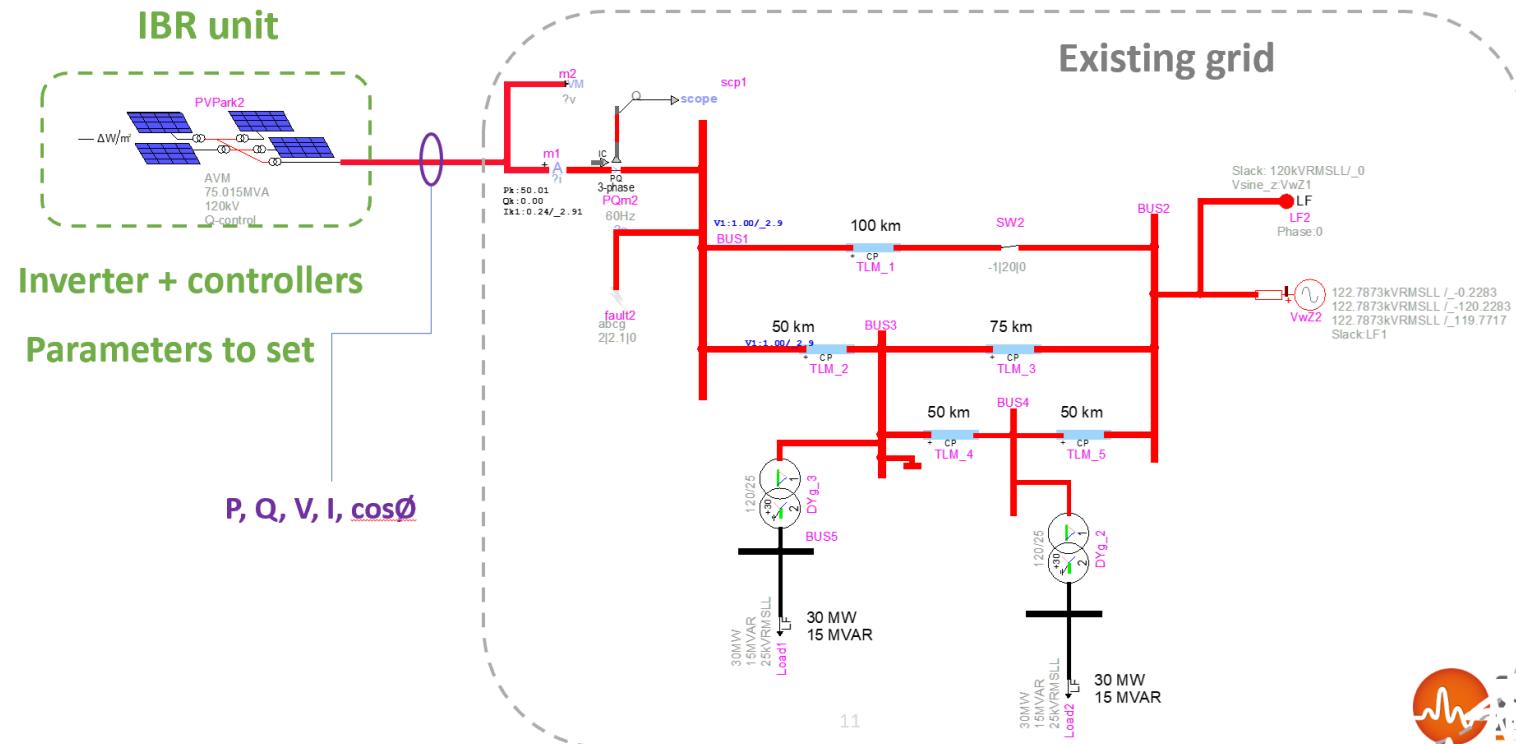
- Let's consider an IBR plant connected to a grid. The plant and the grid are modeled in EMTP, but we do not know the settings of some parameters in the IBR model (controller gains, time constants, etc...).
- On-site measurements of the physical plant response in some operating conditions are available.
- A tool has been created in EMTP to automatically determine some unknown IBR plant parameters values by fitting the IBR model response to on-site measurements.



II. Automatic model parameter determination

Context:

- The tool performs the following tasks automatically:
 - Assign values to some parameters of the plant model,
 - simulate the model and get the plant response,
 - compare the simulation results with expected waveforms (experimental measurements),
 - update/modify parameters values and redo the process until the perfect match is found.
- Parameters update process is performed using an artificial intelligence method known as **the particle swarm optimization (PSO) algorithm**.



II. Automatic model parameter determination

An overview or the particle swarm optimization (PSO) algorithm:

- Several entities (particles) are searching for the best solution.
- It is an iterative process (instant1, instant2, instant3, etc...).
- At each iteration (instant), each particle has a **position**, a **velocity** and a **cost**.
- At each iteration (instant), each particle position is updated based on past knowledge.

$$P_i^{t+1} = P_i^t + V_i^{t+1} \quad \text{Particle position update}$$

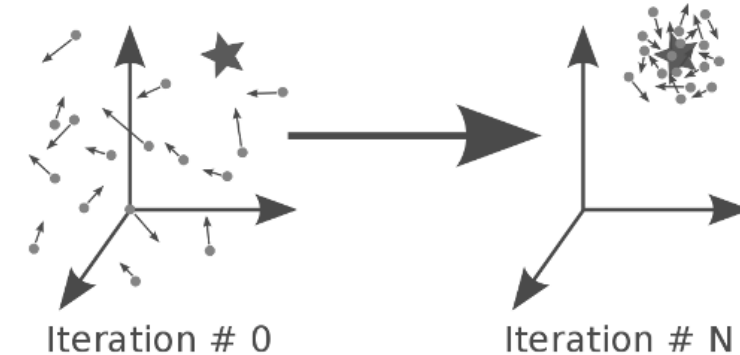
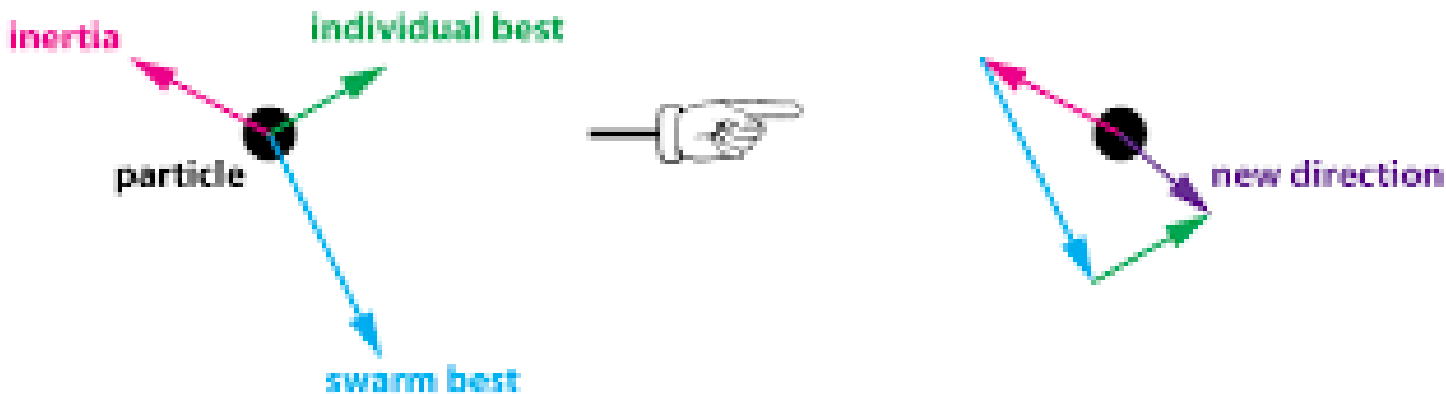
$$V_i^{t+1} = W \cdot V_i^t + c_1 U_1^t (P_{b_1}^t - P_i^t) + c_2 U_2^t (g_b^t - P_i^t)$$

Velocity update

Inertia : Makes the particle move in the same direction and with the same velocity.

Personal Influence : Improves the individual. Makes the particle return to a previous position, better than the current.

Social Influence : Makes the particle follow the best neighbors direction.



II. Automatic model parameter determination

PSO applied to parameter determination Ex: estimating the PI controller gains of the reactive power control

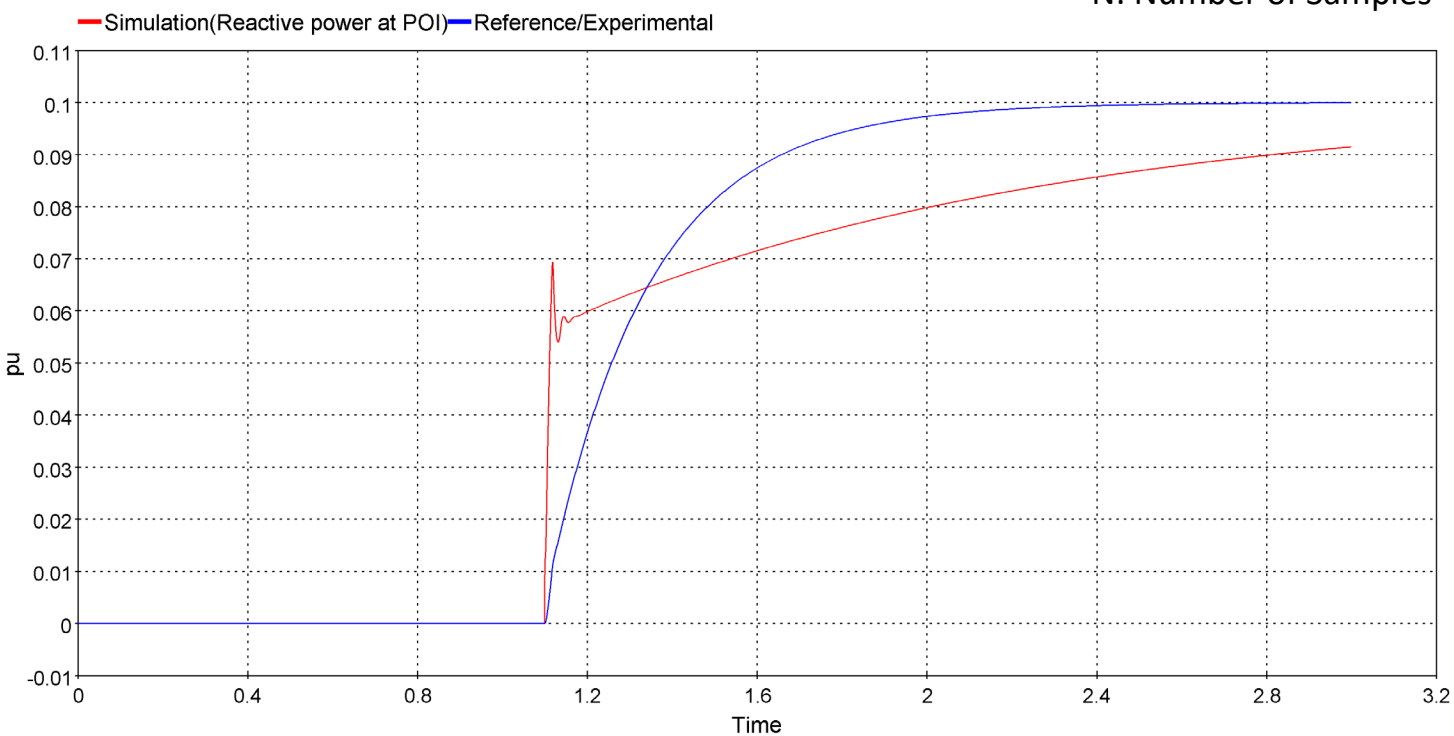
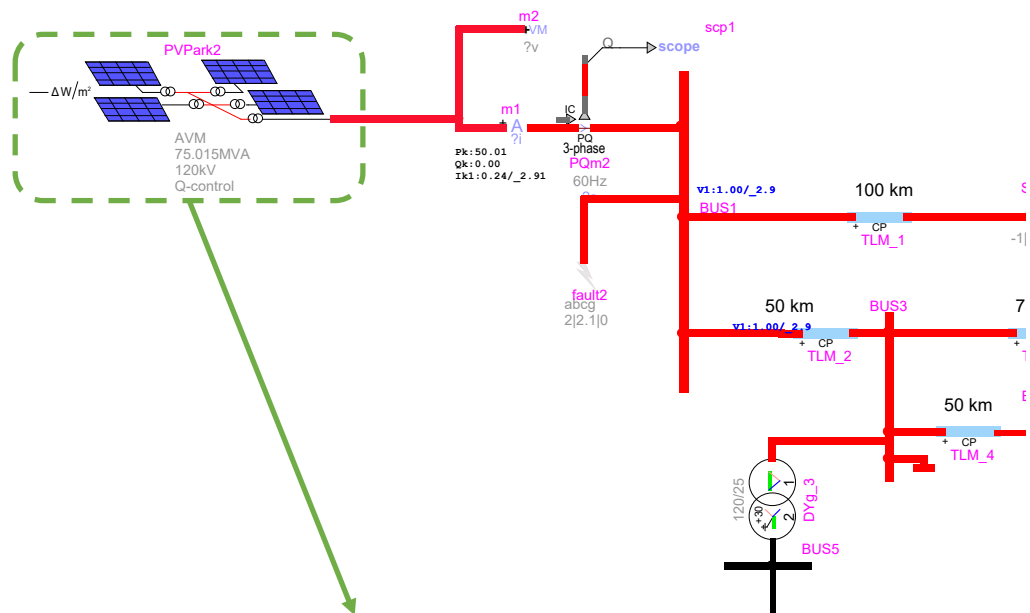
The blue line represents the on-site measurement of the plant response to a Q-step change

Each value of K_p and K_i (a particle position) yields a specific plant response (red line)

Cost function:

$$\sum_{i=0}^{i=N} |f_{Exp}(i) - f_{sim}(i)|$$

N: Number of Samples



Properties for PV park PVPark1

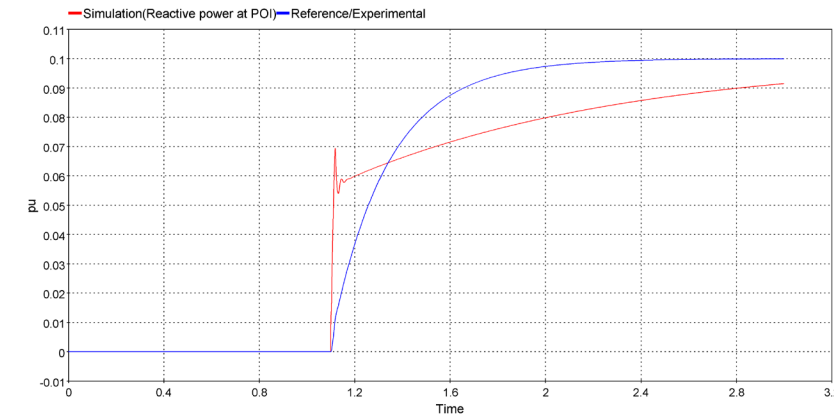
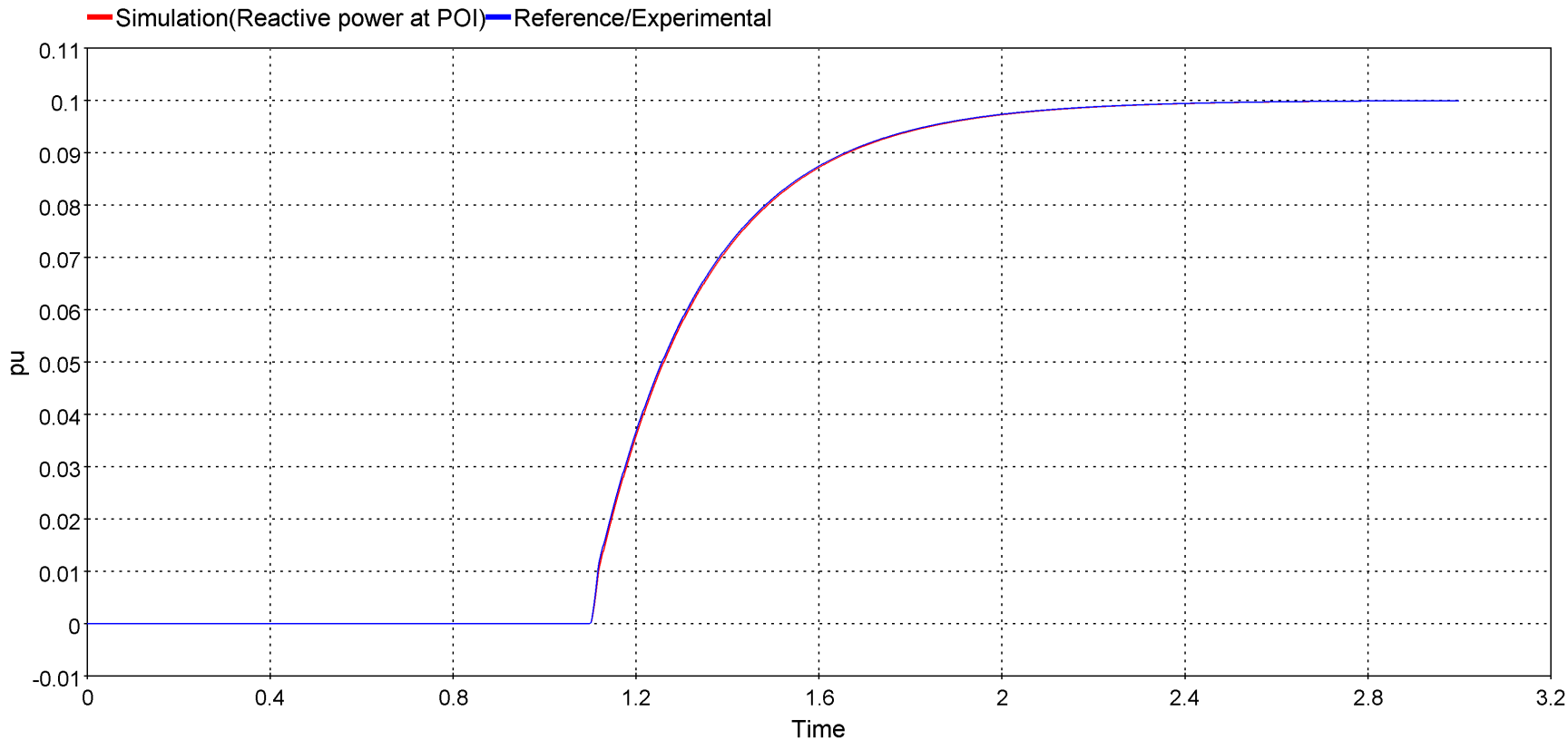
General	PV module	Park Transformer	Inverter Transformer	Converter control	Prot
V-control K_v					1.75
Q-control K_p					2.09
Q-control K_i					18.56
Maximum output Q command					1 pu
Minimum output Q command					-1 pu

The goal is to find K_p and K_i so that the red line (simulated) fits the blue one (measurement).

II. Automatic model parameter determination

PSO applied to parameter determination Ex: estimating the PI controller gains of the reactive power control

The PSO algorithm performs iterations and stops as soon as the cost associated to a particle gets lower than a predefined threshold. The corresponding particle value is taken as the final solution (K_p and K_i).



	Final solution	Expected value
K_p	0.08	0.1
K_i	5.4	5.5

II. Automatic model parameter determination

The automatic model parameter determination has been implemented in EMTP using the tool development capability presented at the beginning. The next section presents the tool itself.

III. The IBR data fit tool

III. The IBR data fit tool

Launch the tool

The screenshot displays the EMTSoft EMTWorkbench interface. The title bar shows the file path: `C:\Program Files (x86)\EMTPWorks 4.2.0\Toolboxes\IBR_data_fit\Examples\IBR_data_fit\EPRI_Benchmark_PV_example.ecf - EMTWorks`. The menu bar includes: File, Home, Options, View, Design, Short-circuit, Simulate, ETRV, E-Energize, E-interconnect, **IBR_data_fit**, Parametric, Import. The **IBR_data_fit** menu is circled in red, and its options are: Open IBR_data_fit interface, Open IBR_data_fit documentation, and Open IBR_data_fit.

The main workspace shows a power system diagram with the following components:

- PVPark1**: A PV park with parameters: $\Delta W/m^2$, AVM, 75.015MVA, 120kV, Q-control. It is connected to a bus labeled **I_park** with parameters: Pk: 50.01, Qk: 0.00, Ik1: 0.24/_2.91.
- IBR Data Fit**: A tool window titled "IBR Data Fit" with a sub-window "PVPark_d.dwj".
- fault1**: A fault source with parameters: abcg, 2|2.1|0.
- IBR_data_fit_Sim_data scope**: A scope connected to the system.
- BUS1**: A bus with parameters: v1: 1.00/_2.9.
- Transmission Lines**: TLM_12 (100 km), TLM_13 (50 km), TLM_23 (75 km), TLM_34 (50 km), and TLM_24 (50 km).
- BUS2**: A bus with a slack of 120kVRMSLL/_0 and a window sine wave source **VwZ1** with parameters: 122.7873kVRMSLL /_-0.2283, 122.7873kVRMSLL /_-120.2283, 122.7873kVRMSLL /_-119.7717, Slack: LF1.
- BUS3**: A bus with parameters: v1: 1.00/_2.9.
- BUS4**: A bus connected to two transformer units.
- BUS5**: A bus with parameters: 120/25, 430, 2, DYg_4, 30 MW, 15 MVAR, 30MW, 15MVAR, 25kVRMSLL, Load6, LF.
- Transformer Units**: Two units with parameters: 120/25, 430, 2, DYg_1, 30 MW, 15 MVAR, 30MW, 15MVAR, 25kVRMSLL, Load6, LF.

A small graph in the bottom left corner shows a plot of $\frac{dP}{dt}$ versus time, with a red curve showing a transient response.

On the right side, the "Parts by Library" panel lists various components: Control, Control Functions, DC, E-Interconnect, ETRV, Exciters And Governors, Flip Flops, FMI, IBR_data_fit, Lines, Load Models, Machines, Meters, Nonlinear, Options, Parameter Sweep, Phasors, Power Electronics, Protection, Pseudo Devices, Renewables, RLC Branches, SimulinkDLL, Sources, Switches, Symbols, Transformations, and Transformers.

III. The IBR data fit tool

Step 1 : Select parameters to vary

C:\Program Files (x86)\EMTPWorks 4.2.0\Toolboxes\IBR_data_fit\Examples\IBR_data_fit\EPRI_Benchmark_PV_example.ecf - EMTPWorks

File Home Options View Design Short-circuit Simulate ETRV E-Energize E-Interconnect **IBR_data_fit** Parametric Import

Open IBR_data_fit interface
Open IBR_data_fit documentation
Open IBR_data_fit

IBR_data_fit panel: EPRI_Benchmark_PV_example.ecf

Steps

[Step 1: Select parameters](#)

IBR device parameters selection

Select the parameters to optimise and set the boundaries

Selected device name: **PVPark1**

Parameters	Default value	Min value	Max value
<input type="checkbox"/> Ngen	45		
<input type="checkbox"/> Freq	60		
<input type="checkbox"/> Vgrid_kVRMSLL	34.5		
<input type="checkbox"/> Vpoi_kVRMSLL	120		
<input type="checkbox"/> Vgen_kVRMSLL	0.575		
<input type="checkbox"/> Vdc_kV	1.264		
<input type="checkbox"/> includeZigZagTransfo	1		
<input type="checkbox"/> ZigZag_R0_ohm	0.1265		
<input type="checkbox"/> ZigZag_LO_H	0.3831e-3		
<input type="checkbox"/> Sgen	1.667		
<input type="checkbox"/> Qfilt	75		
<input type="checkbox"/> Rchoke	0.005		
<input type="checkbox"/> Lchoke	0.15		
<input type="checkbox"/> includeCollGrid	1		
<input type="checkbox"/> R_Coll_Grid_Ohm	0.1265		
<input type="checkbox"/> L_Coll_Grid_H	0.3831e-3		
<input type="checkbox"/> C_Coll_Grid_F	7e-6		
<input type="checkbox"/> Ngen_in_service	30		
<input type="checkbox"/> QC_select	1		
<input type="checkbox"/> Qpoi_pu	0		
<input type="checkbox"/> pf_poi	1		
<input type="checkbox"/> Vpoi_pu	1		
<input type="checkbox"/> adjust_Qpoi_pu_withLF			
<input type="checkbox"/> PC_select	1		
<input type="checkbox"/> Pref_poi	1		

EPRI_Benchmark_PV_example.ecf

The diagram illustrates a power system model. On the left, a PV park (PVPark1) is represented by a solar array and an inverter (AVM) with parameters: 75.015MVA, 120kV, and Q-control. The PV park is connected to a bus labeled 'L_park'. This bus is connected to a 3-phase PQM1 inverter through a transformer (PQ) with parameters: 50.01, 0.00, and 0.24/2.91. The system includes several buses: BUS1, BUS3, and BUS5. Transmission lines (TLM_12, TLM_13, TLM_34) connect these buses with lengths of 100 km, 50 km, and 50 km respectively. A load (Load5) is connected to BUS5, with parameters: 30MW, 15MVAR, and 25kVRMSLL. A fault (fault1) is also shown on the system. The diagram is titled 'IBR Data Fit' and 'PVPark_d.dwj'.

Parts by Library

- ▶ Control
- ▶ Control Functions
- ▶ DC
- ▶ E-Interconnect
- ▶ ETRV
- ▶ Exciters And Governors
- ▶ Flip Flops
- ▶ FMI
- ▶ IBR_data_fit
- ▶ Lines
- ▶ Load Models
- ▶ Machines
- ▶ Meters
- ▶ Nonlinear
- ▶ Options
- ▶ Parameter Sweep
- ▶ Phasors
- ▶ Power Electronics
- ▶ Protection
- ▶ Pseudo Devices
- ▶ Renewables
- ▶ RLC Branches
- ▶ SimulinkDLL
- ▶ Sources
- ▶ Switches
- ▶ Symbols
- ▶ Transformations
- ▶ Transformers

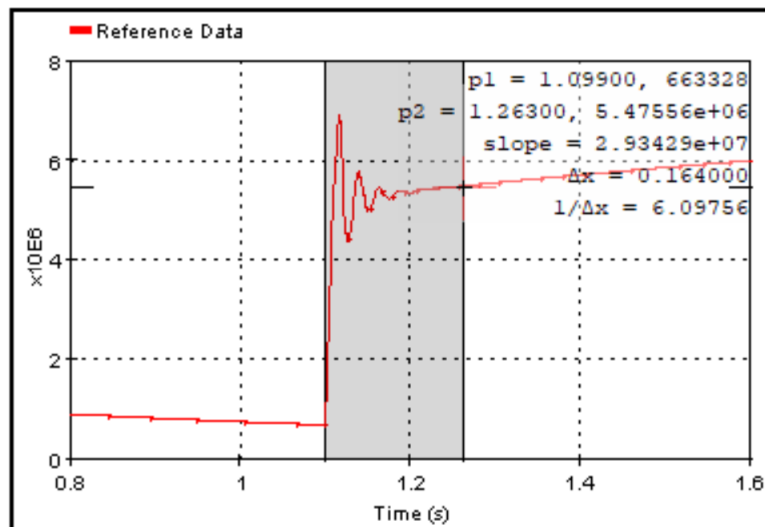
III. The IBR data fit tool

Step 2 : Simulation data definition

Steps	Simulation data definition
Step 1: Select parameters Step 2: Simulation data definition	Reference and observed signals scopes names Reference data signal scope: "IBR_data_fit_Meas_data" Observed data signal scope: "IBR_data_fit_Sim_data" Define observation interval Observation start time <input type="text" value="1.0"/> s Observation stop time <input type="text" value="2.6"/> s <input type="button" value="Save data"/>

On-site measurements data (reference) are saved in a .dat file.

A scope is added to the EMTP circuit with the name IBR_data_fit_Sim_data at the same location where on-site measurement had been performed.



III. The IBR data fit tool

Step 3: Optimization definition

Steps	Optimisation definition
<p>Step 1: Select parameters</p> <p>Step 2: Simulation data definition</p> <p>Step 3: Optimisation definition</p>	<p>Select the optimisation method <input type="text" value="PSO"/></p> <p>Set parameters for Particle Swarm Optimisation (PSO) method</p> <p>Number of particles <input type="text" value="5"/></p> <p>Inertia coefficient (w) <input type="text" value="1"/></p> <p>Inertia Weight Damping Ratio (kappa) <input type="text" value="0.99"/></p> <p>Personal acceleration coefficient (c1) <input type="text" value="2.0"/></p> <p>Social acceleration coefficient (c2) <input type="text" value="2.0"/></p> <p>Maximum number of iterations <input type="text" value="10"/></p> <p>Cost function type <input type="text" value="Sum Absolute Error"/></p> <p>Convergence tolerance <input type="text" value="1"/> %</p> <p><input type="button" value="Save data"/></p>

III. The IBR data fit tool

Final step: get optimization results

Optimization results are available in a text file located inside the _pj folder with the name IBR_data_fit_Optimization.log

```
IBR_data_fit_Optimization.log - Notepad
File Edit Format View Help

Particle 4:
  Parameter WPC_Kp_Q = 1.3271973499085592
  Parameter WPC_Ki_Q = 7.450000000000001
  Fitting Error = 0.5172316907716248%

Particle 5:
  Parameter WPC_Kp_Q = 1.1800000000000001
  Parameter WPC_Ki_Q = 7.4218384656006595
  Fitting Error = 0.112517674621109%

Beginning of iteration 4.

Particle 1:
  Parameter WPC_Kp_Q = 1.0649655410124638
  Parameter WPC_Ki_Q = 7.840239892782372
  Fitting Error = 1.1460413928558186%

Particle 2:
  Parameter WPC_Kp_Q = 1.06561883335176
  Parameter WPC_Ki_Q = 8
  Fitting Error = 1.3640260917430044%

Particle 3:
  Parameter WPC_Kp_Q = 1.1522625841229421
  Parameter WPC_Ki_Q = 7.415175994984397
  Fitting Error = 0.23050843701221338%

Particle 4:
  Parameter WPC_Kp_Q = 1.280909012068068
  Parameter WPC_Ki_Q = 7.809435885968085
  Fitting Error = 0.7711510602746205%

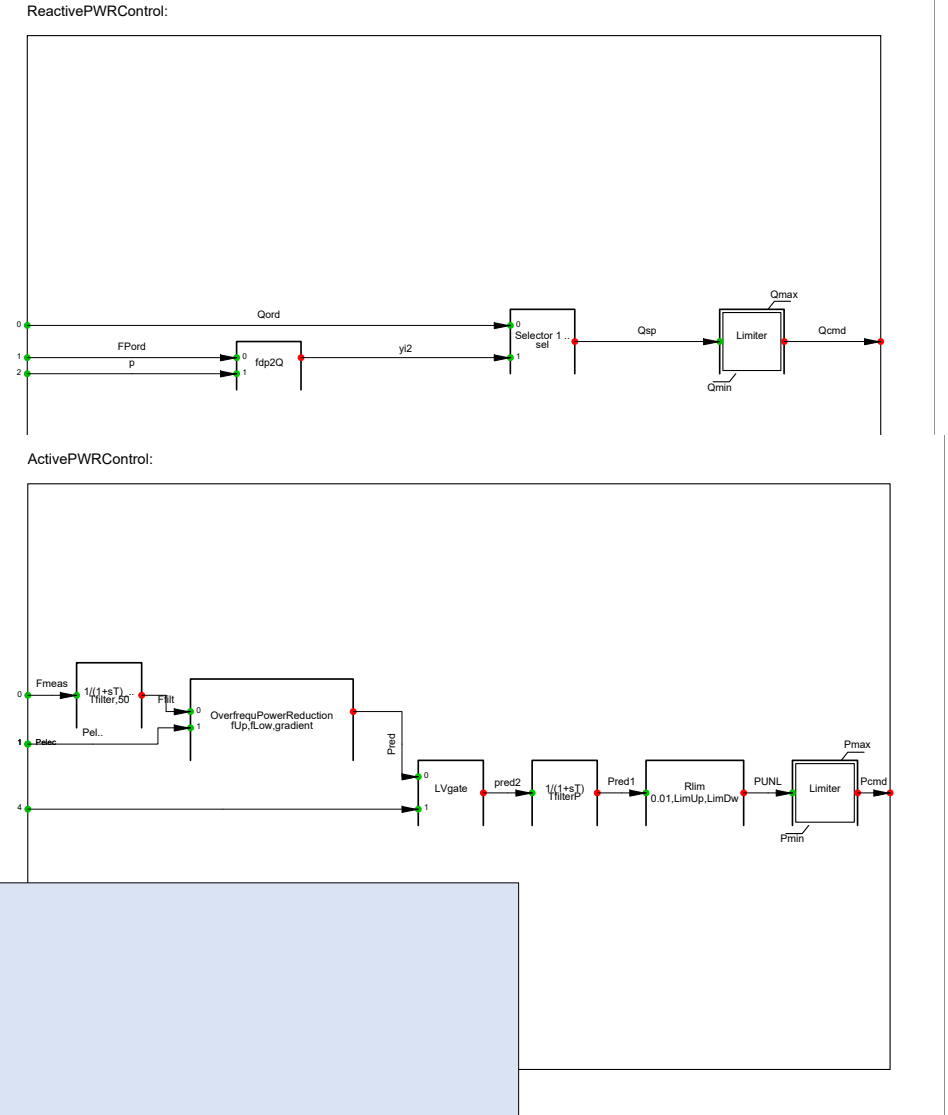
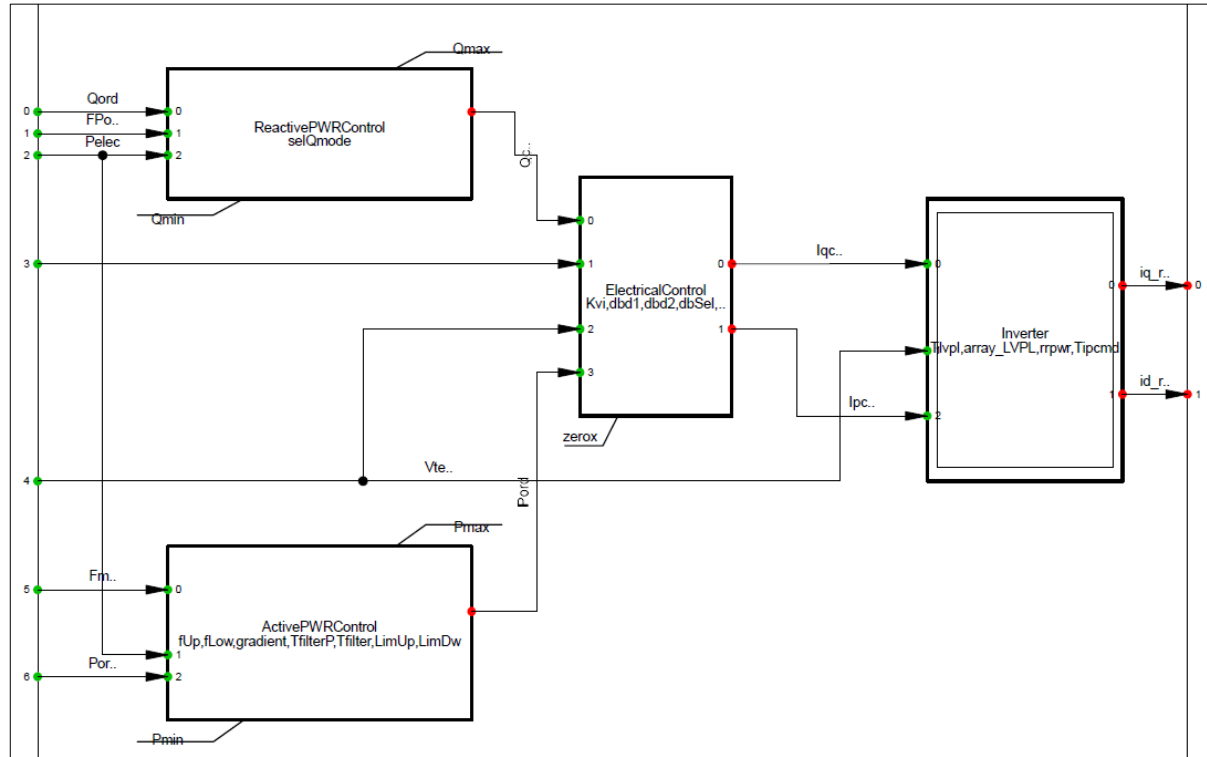
Particle 5:
  Parameter WPC_Kp_Q = 1
  Parameter WPC_Ki_Q = 7.411453598670608
  Fitting Error = 0.9568641242589233%

**Optimal parameters values**
Parameter WPC_Kp_Q: 1.18
Parameter WPC_Ki_Q: 7.422
Final Fitting Error: 0.112517674621109%
```

IV. Case study

IV. Case study

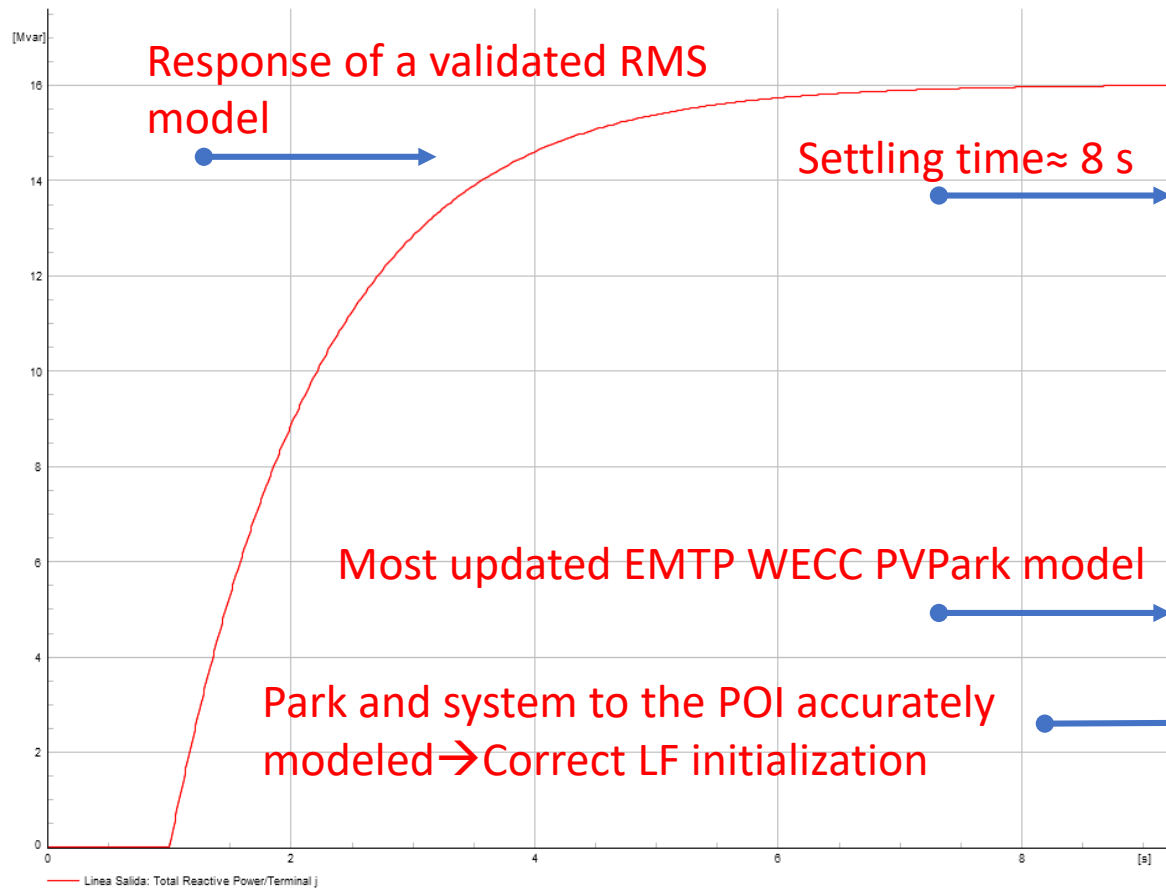
Calibration of a NON-WECC Model (extremely simplified)



- RMS Model validated on site (Step changes, not faults)
- NON-WECC model → More challenging fitting
- Simple control blocks → difficult to translate to a more complex model
- NON WECC model → Almost equivalent to a Black Box model for practical effects

IV. Case study

PPC Parameter Calibration with a Q Step Change of 20% of the Nominal Power of the PV Park



Default values

Simulation data definition

Reference and observed signals scopes names
 Reference data signal scope: "IBR_data_fit_Meas_data"
 Observed data signal scope: "IBR_data_fit_Sim_data"

Define observation interval
 Observation start time: 1 s
 Observation stop time: 8 s

Save data
Go to next step

Optimisation definition

Select the optimisation method:

Set parameters for Particle Swarm Optimisation (PSO) method

Number of particles: 5
 Inertia coefficient (w): 1
 Inertia Weight Damping Ratio (kappa): 0.99
 Personal acceleration coefficient (c1): 2.0
 Social acceleration coefficient (c2): 2.0
 Maximum number of iterations: 4
 Cost function type: Sum Absolute Error
 Convergence tolerance: 2 %

Save data

IBR Data Fit | MPlot

WECC_PVPark_d.dwj

WECC_PVPark_1

REEC_D_REGC_A
80.0400MVA
220kV
Q-control
IBR_data_fit_Meas_Data

IBR_data_fit_Sim_data scope

BUS_1
v1:1.00/-0.2

DEV2
Vpu

Eeq_220kV
v1:1.00/-0.0

VwZ1
220kVRMSLL/_0
Slack:LF1

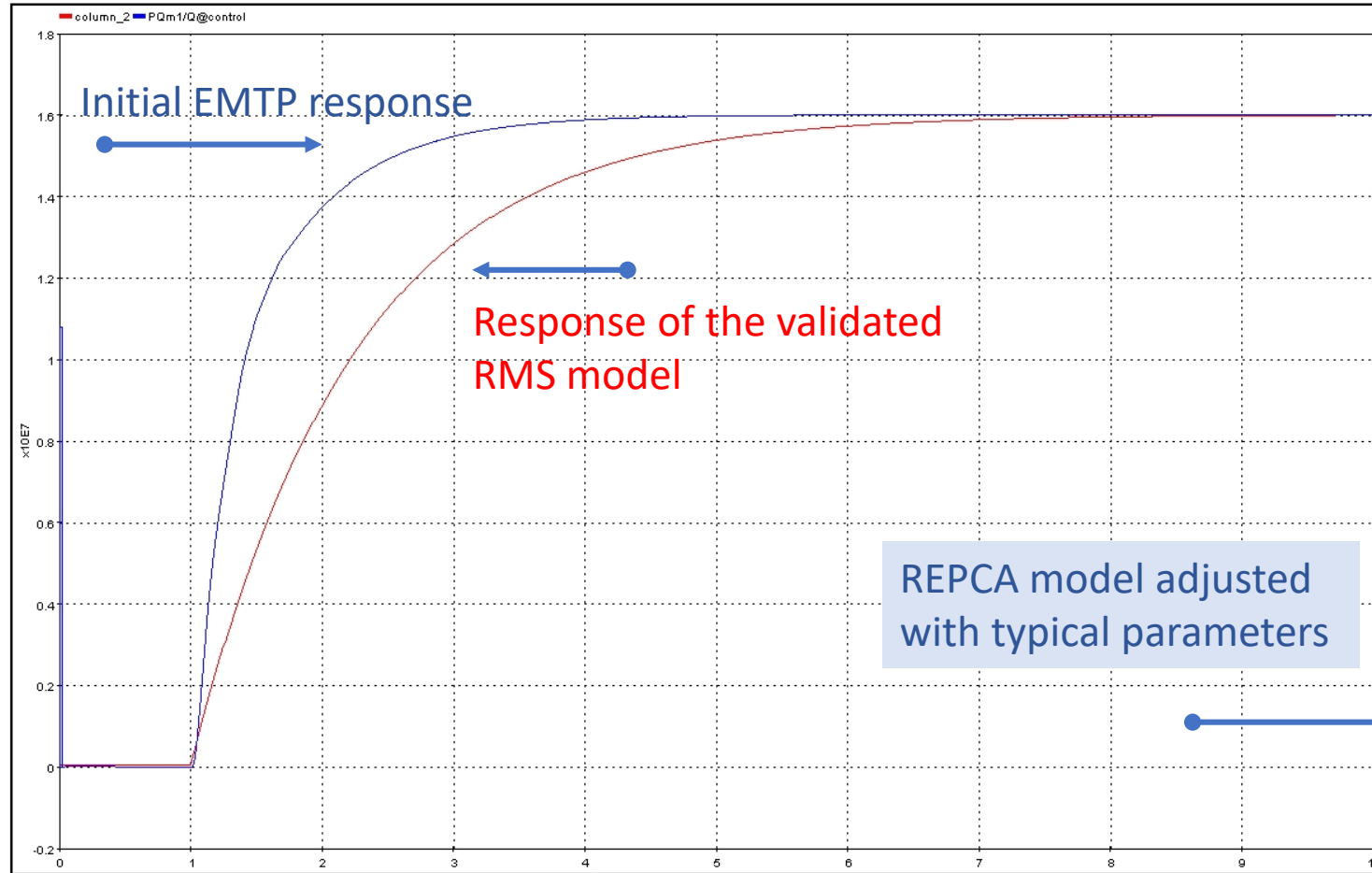
LF1
Slack: 220kVRMSLL/_0
Vsine_z\VwZ1

fault1
abcg 1|1.12|0

50Hz, 1E6VA
Load-Flow solution
View Steady-State

IV. Case study

CASE 1: Default values for the REPC WECC_PV_Park Model

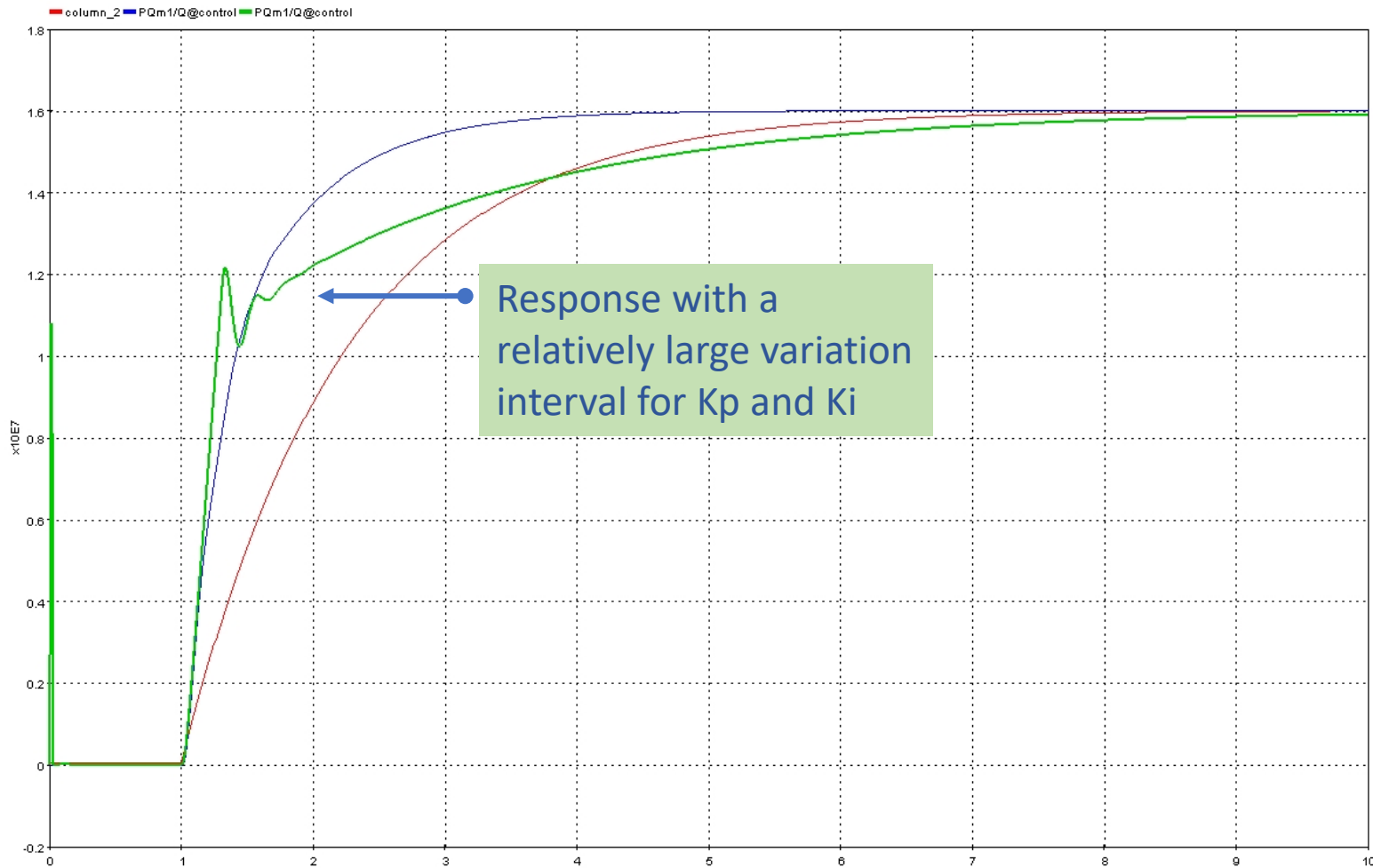


Q/V control - REPCA model	
Voltage droop control	droop control
Time constant T _{ftr}	0.02 s
Proportional gain K _p	0.5 pu
Integral gain K _i	2.5 pu
Lead time constant T _{fl}	0 s
Lag time constant T _{fv}	0.05 s
Voltage V _{frz}	0.7 pu
Compensation resistance R _c	0 pu
Compensation reactance X _c	0 pu
Compensation gain K _c	0.02 pu
Upper limit on deadband e _{max}	0.1 pu
Lower limit on deadband e _{min}	-0.1 pu
Lower threshold for deadband dbd1	0 pu
Upper threshold for deadband dbd2	0 pu
Upper limit Q _{max}	0.436 pu
Lower limit Q _{max}	-0.436 pu
Output P and Q command revise time	0.001 s

Parameter K_p_REPC = 0.5
Parameter K_i_REPC = 2.5
Fitting Error = 10.75%

IV. Case study

CASE 2: PSO Optimisation of Parameter K_p _REPC and K_i _REPC with variation intervals set to [0-20]

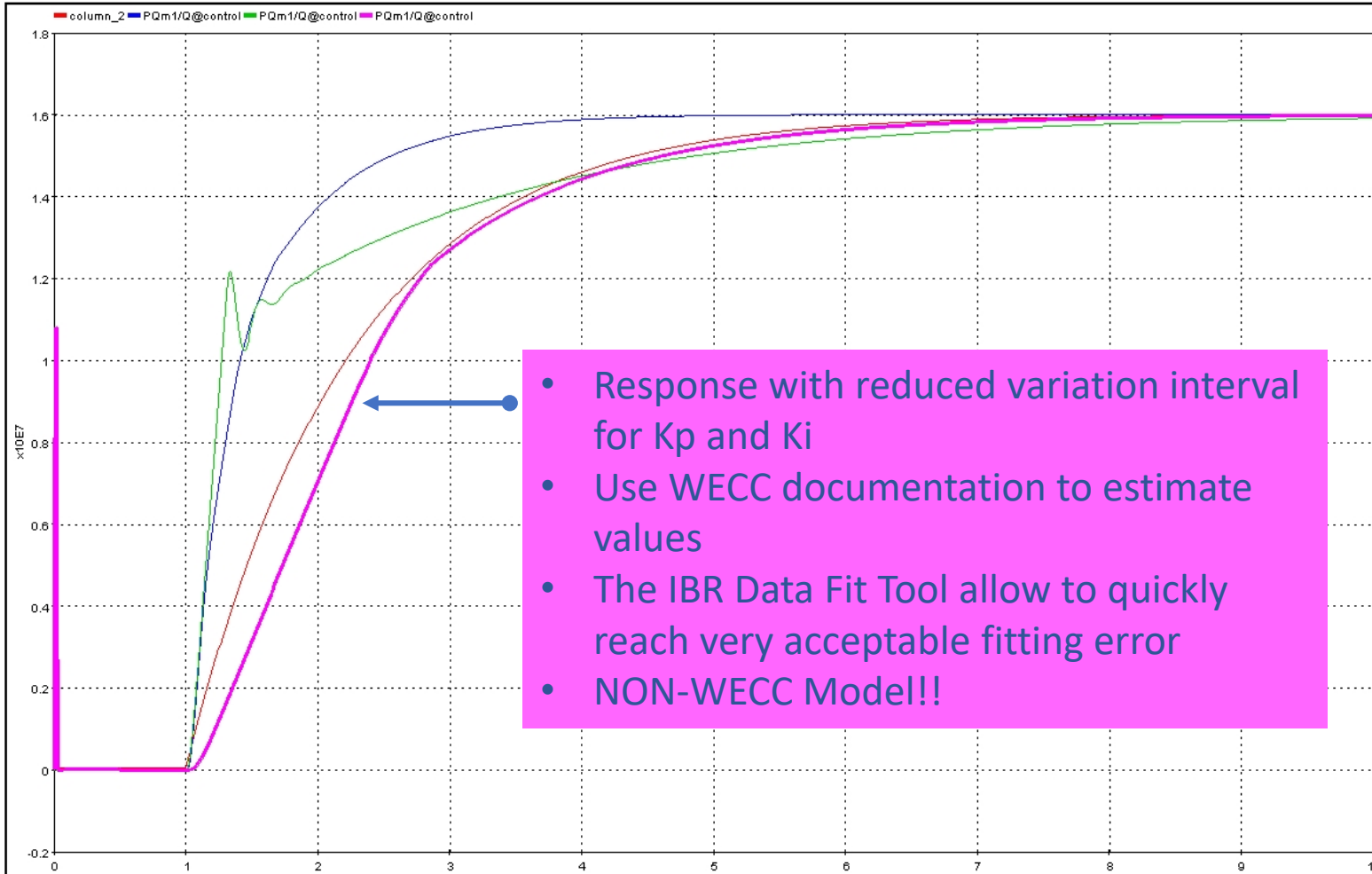


Q/V control - REPCA model	
Voltage droop control	droop control
Time constant T _{filtr}	0.02 s
Proportional gain K_p	1.40945 pu
Integral gain K_i	1.2812 pu
Lead time constant T _{ft}	0 s
Lag time constant T _{fv}	0.05 s
Voltage V _{frz}	0.7 pu
Compensation resistance R _c	0 pu
Compensation reactance X _c	0 pu
Compensation gain K _c	0.02 pu
Upper limit on deadband e _{max}	0.1 pu
Lower limit on deadband e _{min}	-0.1 pu
Lower threshold for deadband dbd1	0 pu
Upper threshold for deadband dbd2	0 pu
Upper limit Q _{max}	0.436 pu
Lower limit Q _{max}	-0.436 pu
Output P and Q command revise time	0.001 s

****Optimal parameters values****
Parameter K_p _REPC: 1.40945
Parameter K_i _REPC: 1.2812
Final Fitting Error: 7.27%

IV. Case study

CASE 3: PSO Optimisation of Parameter K_p _REPC and K_i _REPC with variation intervals set to [0-5]



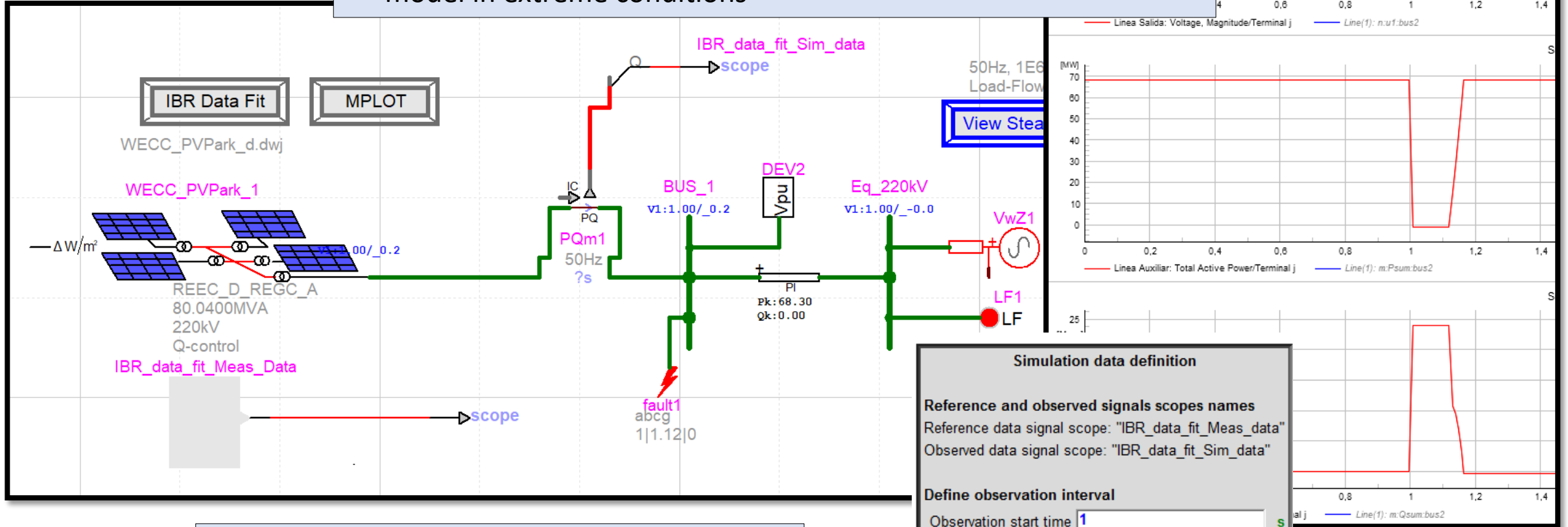
Q/V control - REPCA model		
Voltage droop control	droop control	
Time constant T_{ftr}	0.02	s
Proportional gain K_p	0	pu
Integral gain K_i	0.9699999999999997	pu
Lead time constant T_{fl}	0	s
Lag time constant T_{fv}	0.05	s
Voltage V_{frz}	0.7	pu
Compensation resistance R_c	0	pu
Compensation reactance X_c	0	pu
Compensation gain K_c	0.02	pu
Upper limit on deadband e_{max}	0.1	pu
Lower limit on deadband e_{min}	-0.1	pu
Lower threshold for deadband $dbd1$	0	pu
Upper threshold for deadband $dbd2$	0	pu
Upper limit Q_{max}	0.436	pu
Lower limit Q_{max}	-0.436	pu
Output P and Q command revise time	0.001	s

****Optimal parameters values****
Parameter K_p _REPC: 0
Parameter K_i _REPC: 0.969
Final Fitting Error: 1.5%

IV. Case study

Inverter and Electrical Control parameter calibration with a 3ph-g fault

- 3Ph-g fault in the validated model at POI
- Fault impedance such to reach a deep voltage dip → Test the model in extreme conditions



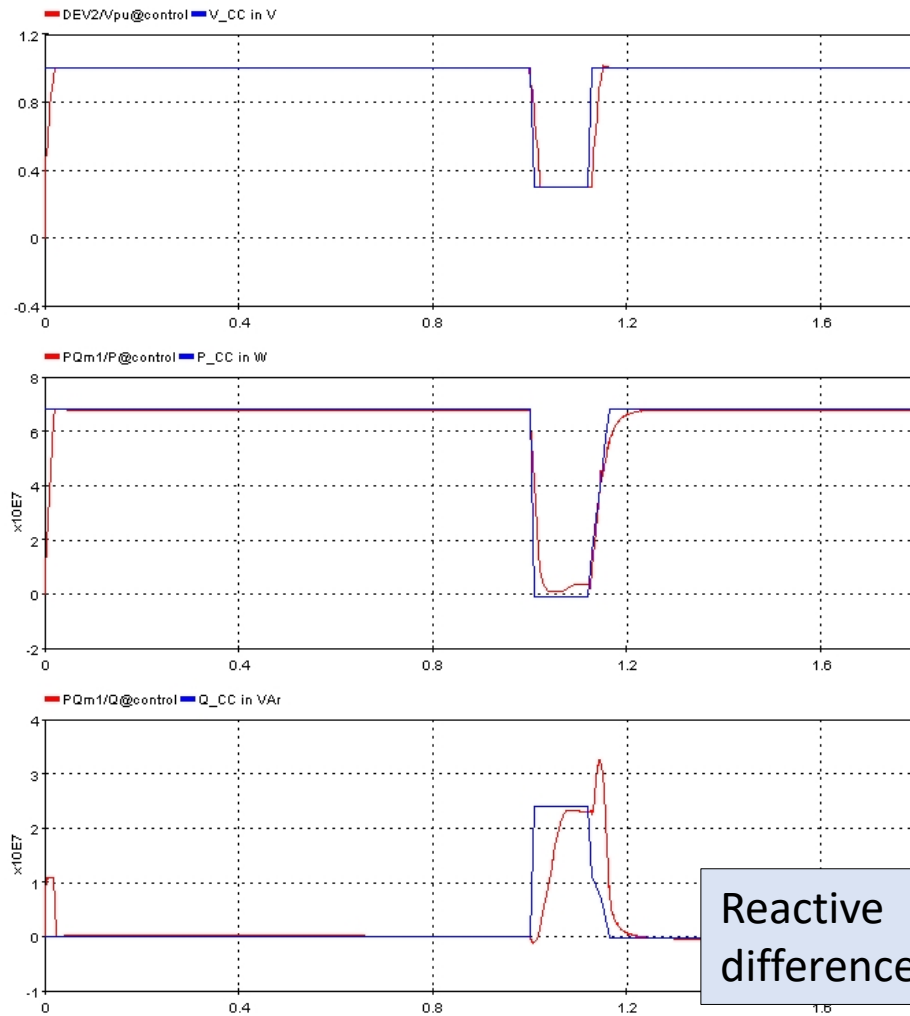
- Transient phenomenon last about 200 ms

IV. Case study

CASE 1: Manually adjusted parameters of the WECC

REGC_A+REEC_D Control Model

Converter model adjusted with typical values and manual simulations



Converter models: **REGC_A + REEC_D Control Model**

Use compiled code for the data acquisition

Use compiled code for the inverter control system

REGC_A converter model

Low Voltage Power Logic: **LVPL Enable**

Converter time constant Tg: **0.01** s

LVPL ramp rate limit Rrpr: **20** pu/s

LVPL characteristic voltage 2 Brkpt: **0.9** pu

LVPL characteristic voltage 1 Zerox: **0.4** pu

LVPL gain Lvpl1: **0.87** pu

Voltage limit Volim: **1.2** pu

High voltage point Lvptn1: **0.1** pu

Low voltage point Lvptn0: **0** pu

Current limit Iolim: **-1** pu

Voltage filter time constant Tftr: **0** pu

Overshoot compensation gain Khv: **0** pu

Upper limit Iqrmax: **20** pu

Lower limit Iqrmin: **-20** pu

Acceleration factor Accel: **1** pu

Generator effective reactance Xe: **0.05** pu

Voltage angle measurement

Proportional-gain Kppl: **100** pu

Integral-gain Kipl: **75** pu

Upper limit wmax: **375** rad/s

Lower limit wmin: **250** rad/s

Active power and reactive power/voltage control - REEC_D control model

Power factor control (PFlag): **Q control (an external signal)**

Voltage/Q/PF control (QFlag): **constant pf or Q control**

P/Q priority (Pqflag): **Q priority**

Baseload flag: **normal operation**

Low voltage threshold Vdip: **0.9** pu

Time constant Trv: **0.002** s

Overshoot deadband dbd1: **-0.1** pu

Upper limit Iqh1: **1** pu

Voltage reference Vref0: **1** pu

Time delay Thld: **0** s

Upper limit Qmax: **1** pu

Upper limit VMAX: **1.5** pu

Proportional gain Kqp: **0** pu

Proportional gain Kvp: **0** pu

Voltage reference Vref1: **1** pu

Up_ramp limit dPmax: **20** pu/s

Upper limit PMAX: **1** pu

Time constant Tp: **0.005** s

Compensation resistance rc: **0** pu

Time constant Tr1: **0** s

Low voltage threshold Vblk1: **0** pu

Time delay Tblk: **0** s

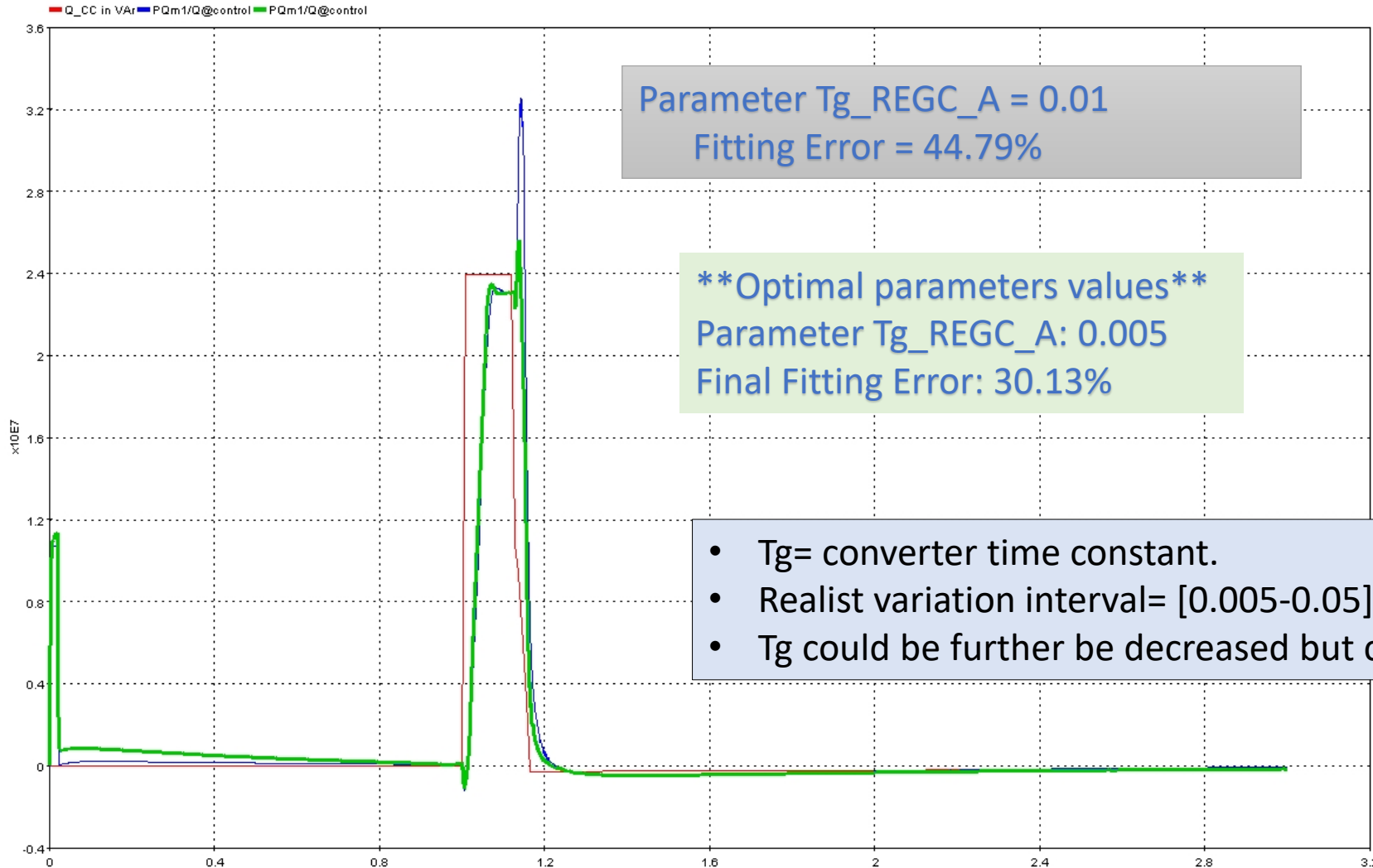
Maximum current Imax: **1** pu

Reactive Power response present the most difference respect to the validated model



IV. Case study

CASE 2: PSO Optimisation of Parameter Tg_REGC_A with variation interval set to [0.005-0.05]

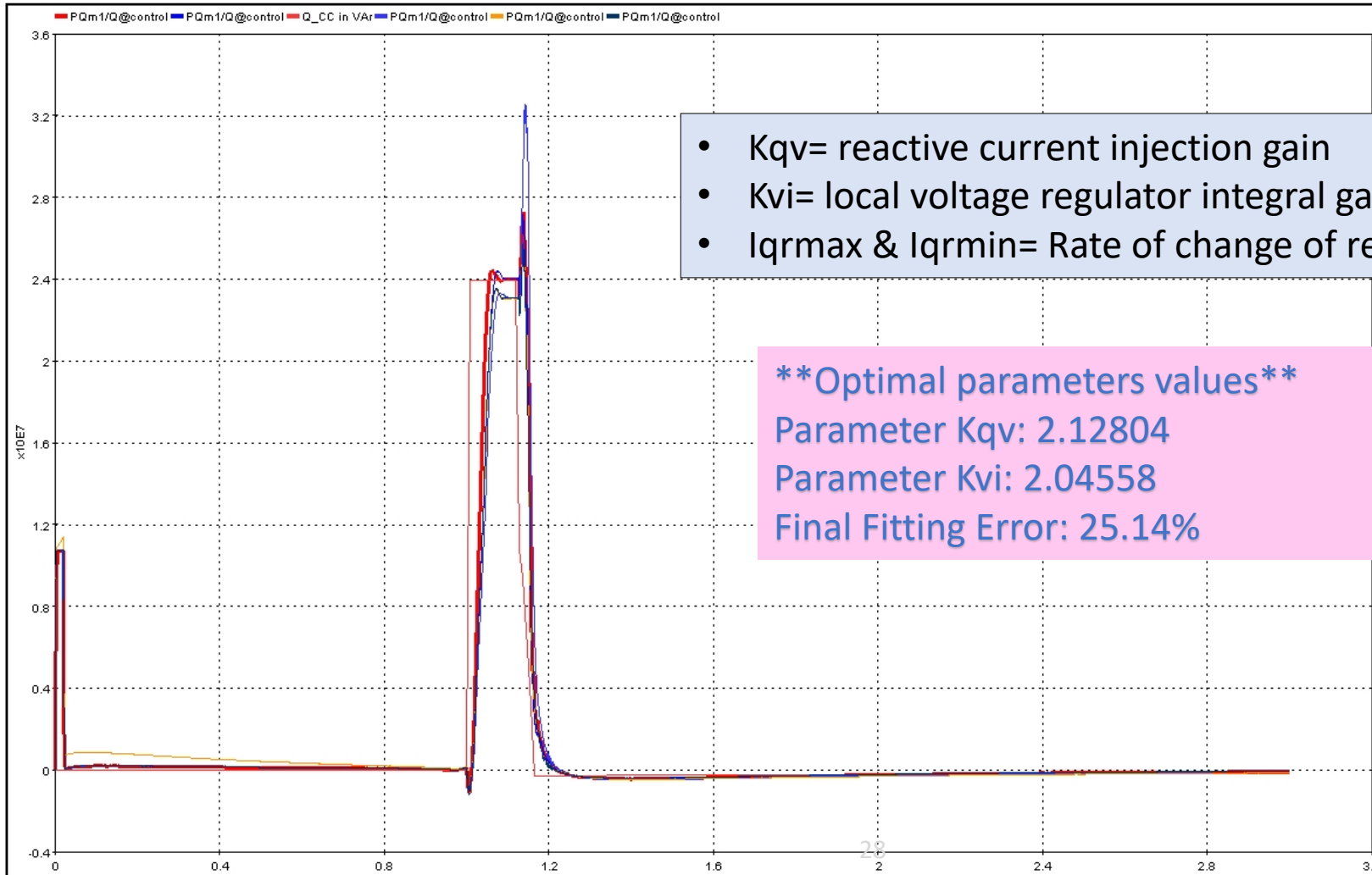


IV. Case study

CASE 3: PSO Optimisation of Parameters of the REEC_D

Kqv_REEC_D [0-5] (2); Kvi_REEC_D [0-5] (0.8)

(with Iqrmax and Iqrmin at maximum)

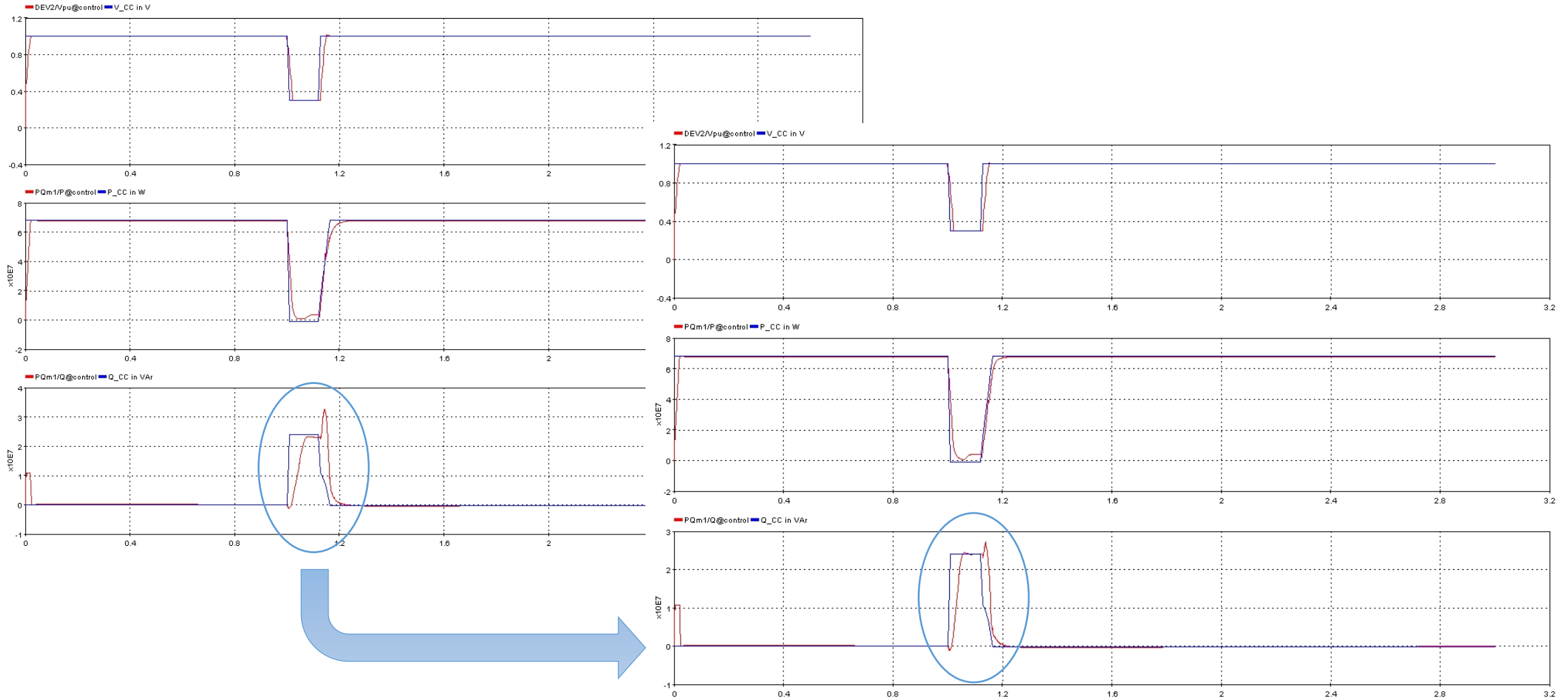


- Kqv= reactive current injection gain
- Kvi= local voltage regulator integral gain
- Iqrmax & Iqrmin= Rate of change of reactive current.

****Optimal parameters values****
Parameter Kqv: 2.12804
Parameter Kvi: 2.04558
Final Fitting Error: 25.14%

IV. Case study

Final Fitting for a 3ph-g fault



- IBR Data Fit Tool useful for the finer adjustment.

V. Conclusions

V. Conclusions

- The initial adjustment of the model parameters is extremely important.
- The IBR Data Fit Tool proved to be particularly effective when the ranges of variation of the parameters to be calibrated were shortened.
- The IBR Data Fit Tool is very effective for finer adjustments.
- The adjustment of non-WECC models (simplified) was more difficult and the IBR Data Fit Tool was particularly useful in this case.

References

B. Poudel, B. Bhandari, E. Amiri, P. Rastgoufard, T. E. Field and R. A. McCanne, "*Interconnection Study and Optimization of Grid Connected Photovoltaic System Using Electromagnetic Transient Program*," 2021 IEEE Kansas Power and Energy Conference (KPEC), 2021, pp. 1-6, doi: 10.1109/KPEC51835.2021.9446233.