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CROSS-CURRENT COMPENSATION MODEL

TO: WECC MVWG & EPRI P40.016
FROM: POUYAN POURBEIK, EPRI
SUBJECT: PROPOSED NEW CROSS-CURRENT COMPENSATION MODEL FOR SYNCHORONOUS GENERATORS
DATE: FEBRUARY 20, 2015 (REVISED 3/19/15; 6/12/15)
CC: RANDY RHINIER, DUKE ENERGY

After consultation with R. Rhinier at Duke Energy, at the November WECC MVWG meeting EPRI made a brief presentation on concerns related to modeling of cross-compensation for synchronous generators in the current simulation platforms [1]. What was presented may be summarized as follows:

1. None of the models in the current commercial tools used in WECC (all the software vendors were present at the meeting and confirmed this statement at that time) allow for reactive current feedback; they all assume total (complex) current feedback into the current compensation model. The actual equipment (at least three vendors we've check with) use reactive current feedback.

2. None of the models in the current commercial tools used in WECC (again confirmed by software vendors) allow for more than two units in the current compensation models.

With the above in mind, if:

- we ignore the limits on the current compensation feedback (imposed in some actual equipment), and
- we assume the Xcomp's (compensation terms) are identical, and
- we assume there are only two units and the units are of the same MVA, and
- we assume the units are at the exact same real power loading on both units (then active current components cancel each other)

then the current models in GE PSLF™, Siemens PTI PSS®E and PowerWorld all can be made to work and can be shown (with some algebra) to be equivalent.

All this said, we believe it is prudent to pursue establishing a new cross-current compensation model that is simpler and more general (i.e. allows for more than two units) because actual equipment more closely mimics the proposed model below.

The proposal is to:

1. Make the current feedback be the reactive component of current only (at least three major excitation system vendors have confirmed that they only use reactive current feedback; that is the imaginary component of total complex terminal current of the generator).

2. Allow for up to four (4) machine to be linked by cross-current compensation. There are large utilities pursuing up to at least four units being coupled on a single bus with cross-current compensation.

Thus, the proposed model becomes:

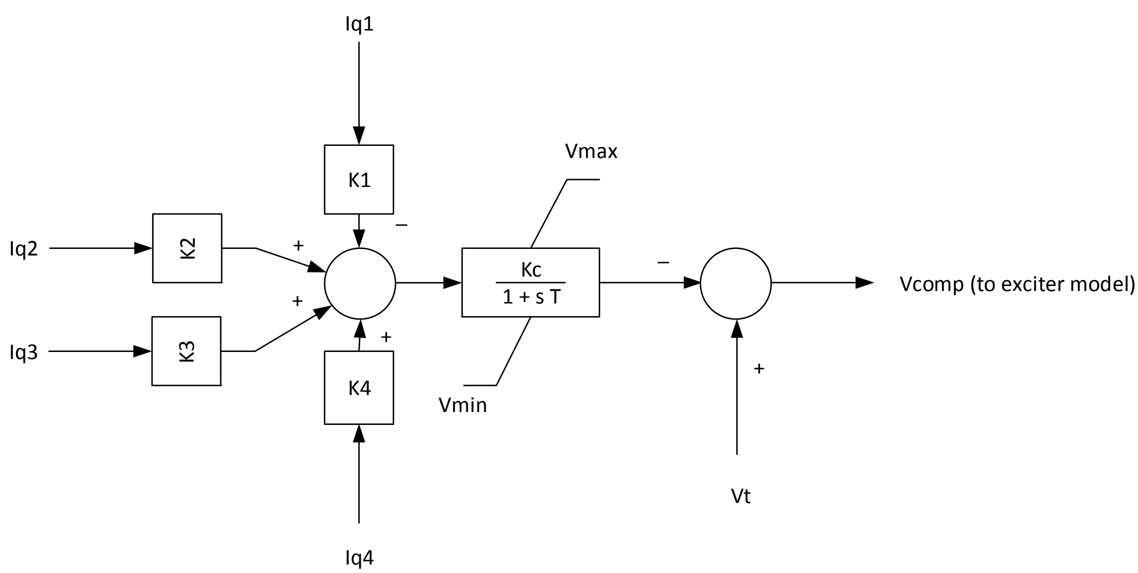

Figure 1: Proposed new cross-current compensation model (proposed name of the model: **CCOMP4**[1])

The parameters of the model would be:

T – time constant

Vmax/Vmin – max and min on output

K1, K2, K3, K4 – the compensation constants

Kc – overall loop gain; typically set to 1 but can be set differently

[1] This name, CCOMP4, was suggested and decided upon during the WECC MVWG meeting on 3/19/15 in Salt Lake City, UT.

There will also need to be a means to allow the model to reference up to three other generators. The four generators may not necessarily be on the same bus (e.g. two units on separate windings of a three winding GSU), but in the most typically cases they are. The model can be used for 1, 2, 3 or 4 units.

The model is on unit 1, where Iq1 is the reactive component of stator current on unit 1, and Iq2, Iq3 and Iq4 are the reactive components of stator current on the other three units, respectively.

The model should be instantiated separately on each unit for maximum generality and to allow for units of differing MVA etc. The suggested approach is to keep the model on the MVA base of the unit it is connected to. Therefore, on unit 1, for example, Iq1 would be on the MVA based of unit 1 (MVA1), Iq2, Iq3 and Iq4 would come into the model on system MVA base (MVAsys) and then have to be converted to the MVA base of the model before being injected through the gains into the summing junction (i.e. Iq2 = (Iq2_sys * MVAsys) / MVA1) etc.

Appendix A shows actual implementations of the cross-current compensation by two major vendors and thus justifies why the above is the most general form.

<u>Appendix A:</u> Two actual implementations of cross-current compensation.

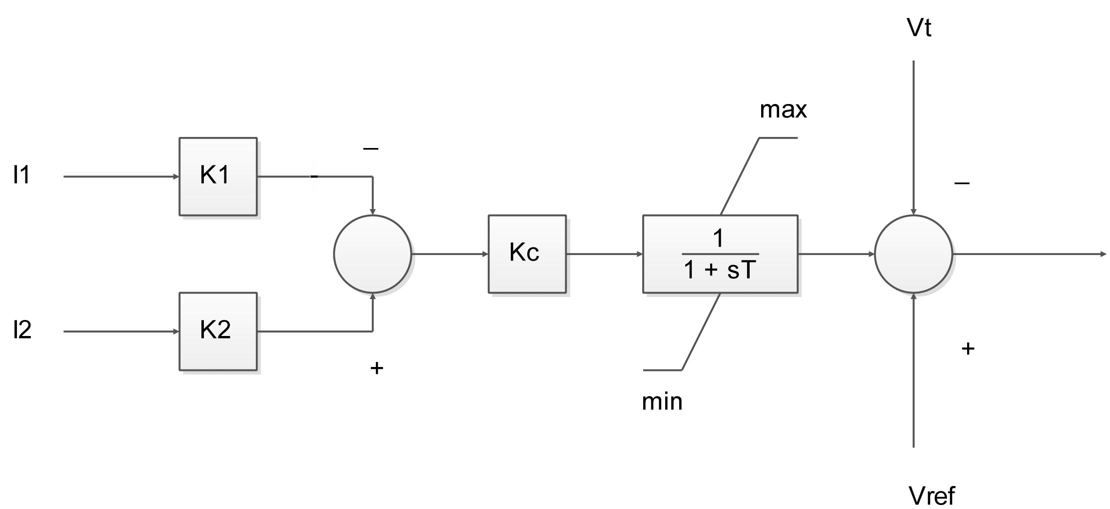

Figure A-1: Vendor 1

$$\text{ADD\_IN-REF1\_A 1} \quad = V_T - [K_{D1} I_{Q1} + K_{C1}(I_{Q2} - I_{Q1})/2]$$

$$\text{ADD\_IN-REF1\_A 2} \quad = V_T - [K_{D2} I_{Q2} + K_{C2}(I_{Q1} - I_{Q2})/2]$$

Figure A-2: Vendor 2

References:

[1] P. Pourbeik, “Comments on Cross-Current Compensation”, November 11th, 2014 presentation at WECC MVWG meeting in Albuquerque, NM.