Memorandum

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TO: WECC LMTF

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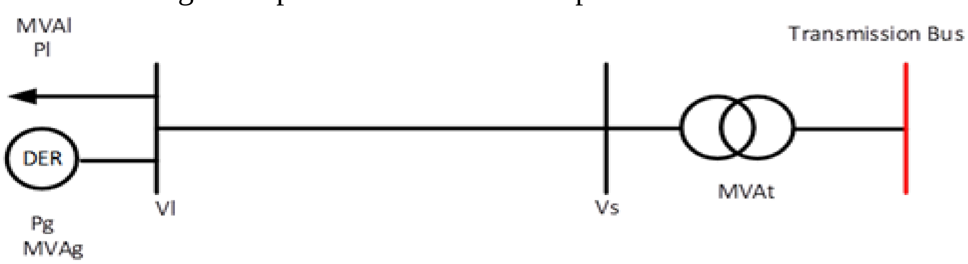
SUBJECT: **SETTING OF MVA BASE IN THE CMPLDWG MODEL WITH DER PRESENT**

This document makes an attempt to summarize a vast conversation and discussion around ways in which the MVA base of the CMPLDWg model can be set. The precedence of the discussion is set by first summarizing comments from individual entities followed by drawing an engineering judgement conclusion at the end.

From Pouyan:

Assuming a network diagram representative of the composite load model as shown below,



Where,

- The impedance of the network elements (feeder + transformer) are on a base = MVAt
- The DER base = MVAg which is calculated as |Pg/loading factor|
- The load (sum total) base = MVAl which is calculated as |Pl/loading factor|

There are two plausible options to set the value of MVAt

1) MVAt = max{MVAg, MVAl}, and
2) MVAt = MVAg + MVAl

Both options have inherent assumptions, and downsides as mentioned below:

1) In option 1, the assumption is that the feeder is built to handle the larger rating of either DER or load.
    a. However, the downside is that, for a scenario wherein the DER is operating in a charging mode, then the total load on the feeder would be Pg + Pl, but the MVA rating would be a lower value.
2) In option 2, the assumption is that the feeder is built (upgraded) to accommodate the maximum possible loading (which occurs when load and 'charging' – e.g. EVs – are at a coincidental peak)
    a. However, the downside is that for a majority of load and DER MW conditions, the MVA base value would be an overestimated.

To summarize both options, Option 1 will be quite pessimistic in a small number of cases, while Option 2 might be optimistic in the majority of cases

From PowerWorld:

Alternatively, the value of MVAt can be set to |Pg| + |Pl| (henceforth denoted as Option 3). The reason to not use loading factors is because, the loading factors ***are not related*** to the choice of the MVA base for the distribution equivalent (transformer and feeder, the first 17 parameters of the PSLF DYD CMPLDW model). There are 4 loading factor parameters (LFa, LFb, LFc, and LFd) which are used to calculate the MVABase for the motors A, B, C and D. The distribution equivalent MVAt is what we are are dealing with in this discussion, and the loading factors are not used in the calculation of that at all.

Presently, in PowerWorld Simulator, the value of MVAt is being set on a value proportional to only the Load MW (|Pl|) (with the distributed generation MW removed). The source code has the following comment to serve as a guidance for the reason behind this calculation.

```
// convert feeder and transformer impedances to the system Base
// Distribution Equivalent Impedances should be based on the Load MW only.
//   Jamie Weber had this discussion with the NERC LMTF group including
//   Bill Price from GE in May 18, 2016 at meeting it PECO in Washington DC
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However, this is a problem because it means that if the Distributed Generation (|Pg|) is much larger than the load, then the feeder/transformer impedances are going to be based on a highly inappropriate value of MVAt. The numerical solutions are then just going to fail badly and strangely.

From EPRI

Based on feeders studied, the transformer MVA specified in the distribution data files is on an average at least 1.5 times the total load. Some examples of the load and transformer rating of the feeders that have been studied,

1. peak load is 10 MW, the transformer MVA is around 25 MVA.
2. peak load of 4 MW with transformer rating of 20 MVA.
3. peak load of 7.6 MW with transformer rating of 25 MVA
4. peak load of 4.7 MW with transformer rating of 12 MVA
5. peak load of 9.0 MW with transformer rating of 25 MVA
6. peak load of 7.0 MW with transformer rating of 10 MVA
7. peak load of 75.0 MW with transformer rating of 120 MVA (3 parallel transformers of 40 MVA each)
8. peak load of 52.0 MW with transformer rating of 45 MVA

Thus, as on an average most distribution transformers are rated 1.5 times peak load of a feeder's load. However, each transformer usually serves around 3-5 feeders in a metropolitan area, and around 1-3 feeders in a rural area. Due to this, the transformers are usually loaded around 100% of their lowest continuous rating, but due to multiple stages of cooling, they would in reality be loaded to around 70% of their highest continuous rating. As an example, the feeder with a peak load of 7.6 MW and transformer rating of 25 MVA. The same transformer also serves two other feeders with a similar load level. Thus, the transformer is loaded to around 100% of its rating. However, 25 MVA is its lowest continuous rating. The transformer has multiple stages to cooling which allows it to serve, in reality, around 40 MVA without reaching its overload margins. So both Option 2 and Option 3 are reasonable assumptions. Both these options would also ensure good numerical convergence for all values of DER and load.

From GE – PSLF™

This over-sizing should however already be considered in the composite load model. For example, in GE-PSLF™, the loading factor of the composite load model can itself account for the over-sizing that has been seen by EPRI. So, if the *mvabase* for the model is set to -0.67, then presently, the model will automatically set the value of MVAt = 1.5*|Pl|. Therefore, under this scenario, using Option 1 should be numerically alright i.e. if *mvabase* = -0.67, then MVAt = 1.5*max(|MVAg|,|MVAl|). Under this scenario, if Option 2 or Option 3 is considered, it might become overly conservative. A note of caution regarding this is that if *mvabase* is entered as 0, then by default a loading factor of 0.8 is assumed. However, if *mvabase* is positive, then presently it is simply taken as the base and no further computations are done.

From Siemens PTI PSS®E

Additionally, there is a possible user entry obstacle here. Using Option 1 along with the entered value of *mvabase* would work if the value is set to a negative value, with an absolute value that is less than 1. However, if the value of *mvabase* is actually set to say a value -1.2, which has been seen to be prevalent in a lot of data sets, then MVAt = 0.833*max{|MVAg|, |MVAl|} could again be a limiting value.

From GE – PSLF™

This is however not a conceptual shortcoming. It is a user entry issue for which possibly a data check could be added to the model. Probably, the value of -1.2 seen in most data sets is due to a misunderstanding by whomever created the data set as to the meaning of "loading factor". It is possible that the interpretation was to be MVAt = 1.2 * Pl instead of Pl / 1.2. However, this need not be the scenario. A case can be made wherein this value was intentionally entered since at peak load (the basis for most data sets), the transformer is likely to have fans and pumps running, which increases its capability beyond the nameplate MVA rating (which is the basis for p.u. X). So, the actual MVA base may actually be less than the load MW. This does however seem to be somewhat far-fetched that the transformer would be intentionally rated to be a value lower than the load level, and the entered value of -1.2 value is a mistake and should be changed to -0.8 (or -0.67 or whatever value is agreed upon) in the data sets.

From EPRI

However, this implementation must be carried out with a note of caution as the choice of loading factor for different cases also needs to be discussed. At an actual load bus in a grid, the distribution transformer nameplate rating is fixed (as it is a physical piece of equipment that is already in-service) irrespective of the loading on the transformer, which keeps changing throughout the day. Presently, the NERC document on load modeling advises that the value of loading factor be chosen between -1 and -1.25. However, if a fixed load factor is used, then when the system load changes (i.e, while analyzing a summer peak vs studying a fall off peak case – change in the value of Pl, and possible Pg) the MVA rating of the transformer will change proportionately due to either of these implementation options discussed previously. This may be problematic while studying cases where the impact of progressively higher penetration of DER on the system is being studied. Typically, as the load/DER penetration at the bus increases, the loading factor will be required to change such that the MVA rating of the transformer remains same over a range of load and DER MWs. Beyond a certain level of load growth or DER penetration increase, the distribution transformer would be upgraded to a larger size. Once the MVA base changes, the loading factor would need to be adjusted again to reflect this in the transformer size. This discussion may also applicable to the D-feeder equivalent. However, since the feeder is an equivalent representation, a base change within a reasonable range may not be very impactful on the end results

Conclusion

Based upon the discussion, an initial conclusion would be to set the *mvabase* parameter to a value of say -0.67, and let the model choose the value of **MVAt = (1/0.67)*max{|MVAg|, |MVAl|}**

However, since a loading factor is already used in the calculation of MVAg and MVAl, to avoid a double consideration of the loading factor, the model can chose the value of **MVAt=(1/0.67)*max{|Pg|, |Pl|}**

An additional detail that was discussed was with regard to thresholds levels of load and DER above which dynamic models of load and DER must be modeled. It was decided that the substation transformer and the equivalent feeder must always be modeled. Further, both load and DER must have separate threshold levels in order to decide upon the use of the corresponding dynamic models.