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Transmission transformer tap changer optimisation while minimising system losses using security unconstrained Optimal Power Flow (OPF) techniques

Tuson, Paul Matthew

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TRANSMISSION TRANSFORMER TAP CHANGER OPTIMISATION WHILE MINIMISING SYSTEM LOSSES USING SECURITY UNCONSTRAINED OPTIMAL POWER FLOW (OPF) TECHNIQUES

KEY TO CORRECTION OF COMMENTS

Paul Matthew Tuson

Johannesburg, 2011

Key to correction comments

S2011/2199 - (68%)

1.0 Introduction and overall appraisal

1.1 Noted, thanks.

1.2 Noted, thanks.

1.3 **Uncritical use of the software**

Noted, thanks.

PSS/E is a widely used and validated power system analysis software package internationally (http://www.energy.siemens.com/us/en/services/power-transmission-distribution/power-technologies-international/software-solutions/pss-e.htm). PSS/E has been in existence as a top power system analysis tool since the 1980's.

A verification or validation of the Siemens PSS/E software package was explicitly stated not to fall within the scope of the research. See the last four paragraphs in Section 1.5 – page 7 of the original dissertation, an extract of which is shown below:

> "The purpose of this dissertation however is not to analyse the advantages and disadvantages of the many different OPF techniques nor is it to develop a new mathematical computational technique to minimise Transmission transformer tapping or optimising costs and losses on a power system.
>
> As mentioned previously, the objective of this dissertation is to investigate whether it is feasible to reduce or eliminate Transmission transformer tapping on the Eskom Transmission network. Therefore, the author has used a commercial power system analysis tool in PSS/E for the OPF analysis and the author has assumed that the simulation tool has been tested and verified accordingly to result in feasible OPF solutions."

Going through the Siemens PSS/E software step by step in Section 3 of the dissertation was an attempt to show that the methodology used in the software is sound and makes engineering sense and was not used in a "black box" way.

Please also see the added second last paragraph added to Section 1.5, page 7, of the updated dissertation.

2.0 Technical insight shown

2.1 **More critical of the numerical principles and techniques used by the software**

Noted, thanks.

As in 1.3 above, this was considered outside the scope of the research

2.2 Noted, thanks. The author has been undertaking loadflow, voltage stability, fault, transient stability, small signal stability, dynamic (frequency) stability, protection and harmonic studies on the Eskom Transmission and Distribution systems for over 20 years.

2.3 **Various tables tedious and judicious use of complementary graphs**

Noted, thanks.

Following on from the comments above ("1.3 - uncritical use of the software"), the intention of the tables was to show the improvements resulting from the OPF analysis for each category e.g. reduced tap movements, adjustable shunt devices added, MW/MVArs saved etc., without the reader having to dredge through the formidable spreadsheet analysis.

However in response to your comments, Section 5 of the original dissertation has been moved in its entirety to Appendix F.

2.4 **Checking the results on a sample basis**

Noted, thanks.

2.5 **Explanation given of the OPF and SPF methods are too brief. Explain in an appendix.**

Noted, thanks.

There are literally scores of introductory and advanced textbooks describing standard power flow (SPF) and optimal power flow (OPF) computer analysis techniques. It was not considered part of the scope of work of this dissertation to explain basic SPF and OPF theory.

However in response to your comments, additional paragraphs have been added at the beginning of Section 2.1 (page 13) and in Section 2.4.5 (page 18). A very good introductory article explaining the basics of SPF and OPF [2] has been included in Appendix G.

3.0 Technical insight shown

3.1 **Costs which appear without apparent substantiation – table 6-3.**

Noted, thanks.

Costs were derived from Eskom and recent project experience gained by the author. Table 6.3 has been referenced in the updated dissertation.

3.2 Noted, thanks.

3.3 **Major focus is OPF, application, other methods considered?**

Noted, thanks.

Please see the following sections in the dissertation, where the above points may have already been addressed:

- 2nd bullet of Section 1.4 (page 4)
    - "The PSS/E OPF software does not allow the choosing of *minimising transformer tapping* as an *explicit objective function*, however, the setting of a *quadratic penalty coefficient* [1] in PSS/E enables the tapping of transformers to be reduced or fixed as an *implicit objective function* [1]."
- Last paragraph of Section 3.1.1 (page 28)

  "A feasible optimisation methodology for Eskom in the absence of SCOPF could be to run an OPF to achieve an objective (e.g. reduce taps and losses) and overlay this OPF solution with known operational requirements to

achieve both objectives of loss savings and operational requirements. This is a methodology that a number of SCOPF techniques use except in a more automated and integrated way [22]."

- 4th last paragraph of Section 1.5 (page 7)

  "Pandya and Joshi conclude their paper with a summary of the methods listed above. They conclude that the NLP, QP, IP and AI methods are the most accurate OPF analytical techniques for reactive power optimisation and optimal location of FACTS devices [22]."

- Section 2.4 (page 16)
- Section 2.4.17 (page 22)
- Last paragraph of Section 3.1.6 (page 34)
- The whole of the original Section 8 (Recommendations for Future Work), now moved to the end of the Conclusions section (Section 6 is Conclusions in the updated dissertation), (pp. 59 to 61).

3.4 Noted, thanks.

4.0 Style and presentation

4.1 Noted, thanks.

4.2 Noted, thanks.

4.3 Noted, thanks.

5.0 Style and presentation

5.1 Noted, thanks. In addition, it has encouraged Eskom System Operations (SO), (refer Gavin Hurford) to re-look at running OPF simulations to improve system efficiency.

5.2 Noted, thanks.

6.0 Style and presentation

6.1 Noted, thanks.

6.2 Noted, thanks.

S2011/2262 - (60%)

Thick document which is not accessible to the reader due to sparse use of appendices.

Noted, thanks.

The whole of Section 5 of the original dissertation (OPF Results) has been moved to Appendix F

Section 7 of the original dissertation (Preferred standard tap positions) has been removed as the contents of this section are largely covered in Section 5 of the updated dissertation (Cost comparison between reduced-tapped and fully-tapped transformers) and Appendix C includes a list of recommended tap positions.

The whole of Section 8 of the original dissertation (Recommendations for future work) has been moved to the end of the new *Section 6 – Conclusions* (pp. 59 to 61).

Chapter 2 – candidate could have done more justice to discussion of SPF and OPF, comes across a listing of theory and not a thoroughly understood body of knowledge.

Noted, thanks.

Additional paragraphs have been added at the beginning of Section 2.1 (page 13) and in Section 2.4.5 (page 18).

Chapter 3 – application of OPF methodology to Eskom transmission system. Presented in the style of a software manual. A more scientific approach would have been better.

Noted, thanks.

One of the criticisms of the report is that the PSS/E output files and spreadsheet files are so large it is difficult to check the results for correctness. Going through the Siemens PSS/E software step by step, was an attempt to show that the methodology used in the software is sound and makes engineering sense.

See also the last four paragraphs in Section 1.5 – page 7 of the original dissertation, an extract of which is shown below:

"The purpose of this dissertation however is not to analyse the advantages and disadvantages of the many different OPF techniques nor is it to develop a new mathematical computational technique to minimise Transmission transformer tapping or optimising costs and losses on a power system.

As mentioned previously, the objective of this dissertation is to investigate whether it is feasible to reduce or eliminate Transmission transformer tapping on the Eskom Transmission network. Therefore, the author has used a commercial power system analysis tool in PSS/E for the OPF analysis and the author has assumed that the simulation tool has been tested and verified accordingly to result in feasible OPF solutions."

Chapter 4 – similar studies in other countries – presentation is confusing and doesn't lead anywhere.

Noted, thanks.

Section 4 has been re-structured and re-written with greater use of bullets for clarity and more conclusions resulting from the survey results.

Chapter 5 – author dumps the extensive results of his software investigations on the reader.

Noted, thanks.

Providing high-level summaries of the large amounts of analysis was an attempt to show trends and conclusions arising from the analysis without having to sift through hundreds of Megabytes of spreadsheet data.

Nevertheless, the whole of Section 5 has been moved to Appendix F.

Chapter 6 – Cost comparison

Noted, thanks.

Chapter 7 – this chapter can be moved to an appendix.

Noted, thanks.

Section 7 of the original dissertation (Preferred standard tap positions) has been removed as the contents of this section are largely covered in Section 5 of the updated dissertation

(Cost comparison between reduced-tapped and fully-tapped transformers) and Appendix C includes a list of recommended tap positions.

Chapter 8 – this chapter could sensibly be moved to the conclusions

Noted, thanks.

The contents of Chapter 8 have been moved to the end of the Conclusions section in the updated dissertation (pp, 61 to 63 – Section 6)..

General – It is not clear if the candidate has actually answered his research question

Noted, thanks.

The research showed that by using an OPF methodology with a minimum real and reactive losses explicit objective function and a quadratic penalty implicit objective function applied to tap movements and switchable VAr devices that transformer tapping can be optimised and tap-changers eliminated in some cases while still maintaining a secure system and reducing overall system real and reactive losses on the Eskom system.

This was essentially the title of the dissertation and answers the Problem Statement in Section 1.1. Therefore the author feels that the research question is answered.