2. Executive Summary and Conclusions

Load Flow simulations, during both normal and contingency conditions for the years 2005 and 2010, have been preformed and the results from those simulations have resulted in several transmission system upgrade recommendations. The transmission system should be upgraded from the currently planned configuration in order to have a system that will withstand single contingencies. For the purposes of the load flow analysis, a single contingency refers to one line or transformer being removed from service. The system loading remained the same for both the normal and contingency conditions and was assumed to be equal to the anticipated peak value for that particular year.

The upgrades, which are necessary in order to support the anticipated generation / load schedules and survive a single contingency, are outlined in Table 23 through Table 26. Specific upgrades for the International tie lines can be seen in Table 3 as well. The most significant recommendation was to have a third undersea cable between Morocco and Europe operational by the year 2010.

The currently planned configuration is referred to in this report as the "given" case and the upgraded configuration is referred to as the "recommended" case. The ability to "withstand a single contingency" means that the transmission system operators will have approximately 15 minutes to take corrective action after a contingency event. Failure to take corrective action could result in equipment damage and/or system interruptions (partial or complete). The present value associated with the upgrades recommended in the above mentioned tables is approximately $300 Million USD.

A transmission system loss evaluation has also been performed for normal conditions. The results indicate that transmission losses will roughly be 3.5% of the combined generation in Morocco, Algeria and Tunisia. The transmission losses for the bi-directional case (Algeria exporting to both Morocco and Tunisia) are less than the westerly flow case. The losses for the bi-directional flow case are about 3% of the total generation. Transmission losses in the year 2005 are reduced by about 70 MW (0.5% of total generation) if the recommended changes to the transmission system are implemented.

A maximum power transfer analysis has been completed and the results quantify the amount of "steady state stability margin" the interconnected system has. Like the load flow analysis, the maximum transfer evaluations have been done for both generation schedules associated for the years 2005 and 2010. In addition, both the "given" and "recommended" cases have been evaluated. Table 14 indicates that the Morocco transmission system (ONE) has very little margin in it for the year 2010. All other areas seem to have an adequate amount of transmission for the given amount of load and generation. The transmission system upgrades that were recommended based on the load flow analysis generally result in about a 2 to 4 % increase in the maximum loadability of a system. The importance of the recommended upgrades to the inter-country transfer capabilities is documented in Table 15 and Table 16.

Transient stability simulations have also been performed for the same years and configurations that were studied for the load flow analysis. The simulations consisted of applying three phase faults on important transmission lines and then removing both the fault and the line after an appropriate amount of relay and breaker time. The results indicate that for certain fault conditions one or more generators may go unstable if the protective relaying is not fast enough. One or more generators going unstable has the potential to lead widespread blackout conditions and / or generator shaft damage.

Transient simulations where the fault clearing time was 125 ms (both ends open in this time) resulted in only one case of instability. A fault on the line in Morocco (Laayo225 # 81061 – Boujdour #81057) caused one or more generators to loose stability. Reducing the fault clearing time on this line to between 80 and 100 milliseconds will eliminate the problem. Additional simulations were made assuming that distance relaying was in use in which the breaker closest to the fault would open in 125 milliseconds but the remote end breaker would not open until 300 milliseconds after the fault. This relaying assumption resulted in many cases of instability which are summarized in Table 18 through Table 22. Virtually all of these instabilities can be eliminated by applying pilot wire relaying on the lines listed in the above mentioned tables. The pilot wire simulations assumed the breaker closest to the fault would clear in 125 milliseconds with the remote breaker clearing 150 milliseconds after the fault.

We believe that additional studies could identify opportunities for improving the reliability and integrity of the interconnected North African transmission system. Specific emphasis should be placed on reviewing and verifying the generator data (both dynamic and steady state) that was used in this analysis. Any data inconsistencies discovered during this process should be incorporated in the final PSSE computer model delivered as a result of this project. Additional studies that evaluate the "spinning reserve" requirements along with a through review of the relaying defense plan could be particularly beneficial in preventing country wide blackouts like what was experienced in February 2003.