CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

A pervaporation was applied as a bioethanol purification unit for improving a performance of SOFC system in this research. A selection of appropriate membrane type for pervaporation including hydrophilic and hydrophobic membranes was investigated. A hydrophobic membrane was still considered a suitable membrane type for purifying dilute bioethanol by pervaporation due to low energy consumption, although the availability of this membrane type with high separation factor was one of the concerns particularly when the pervaporation was operated at higher ethanol recovery. Afterwards, a vapor permeation was introduced to install after a hydrophobic pervaporation which was a way to solve the problem of its low separation factor. This proposed purification process can obtain a desired ethanol concentration of 25mol% with higher ethanol recovery. It was found that a hydrophilic type was an appropriate membrane for vapor permeation since it can carry out a higher overall system electrical efficiency than that of the hydrophobic type and also its required membrane separation factor was possibly available in real membrane materials. Although a vacuum pump of hydrophilic vapor permeation consumed high electrical energy at a higher ethanol recovery to remove large amount of steam through a membrane, the total energy requirement was still less than the other case because the required heat is more critical than the required electrical power. Furthermore, there were some conditions at which the system can be operated under energy self-sufficient mode by adjusting proper operating parameters. Based on PTMSP pervaporation regarded as a poorest separation performance among the selected membranes, it can offer the overall electrical efficiency of about 2.4 times when installing an extra vapor permeation unit compared to the case of using a pervaporation alone. Thereafter, ZSM-5/α-Al_2O_3 pervaporation membrane having the highest separation factor ($\alpha_{E/W}$ = 24) among all selected membranes was chosen for the hybrid vapor permeation-pervaporation process. From the system study, it was found that the obtained values for separation factor of hydrophilic vapor permeation at high ethanol recovery ranges

(85-95%) is higher than the separation factor values of hydrophobic pervaporation but these values are still unavailable in real membrane. Moreover, there still remain some useful thermal energy in the SOFC system when using the membrane (ZSM-5/α-Al_2O_3 with $\alpha_{E/W}$ = 24) for pervaporation in the proposed purification process operated at higher ethanol recovery. Finally, the performance of SOFC system integrated with the proposed purification process using this membrane was compared to those of the system using high-energy distillation column to clearly show its efficiency improvement. As a result of the base case study, the overall electrical efficiency received from the proposed purification process (45.46%) can offer about 2 times of the case using a distillation column (22.53%). Particularly at the same ethanol recovery (75%), the hybrid vapor permeation-pervaporation can offer the overall electrical efficiency more than using only a hydrophobic pervaporation (36.46%), indicating that the new proposed purification process in this research has been regarded as the best alternative.

6.2 Recommendations

6.2.1 In the present study, the bioethanol-fuelled SOFC system was investigated using simplified mathematical modeling to demonstrate its feasible performance improvement with the proposed membrane separation processes. It is recommended to develop more sophisticated mathematical models in order to represent more realistic results. The effects of various important operating parameters (e.g. temperature, feed composition and permeate condition) should be investigated to find optimum operating condition and design.

6.2.2 Since a membrane separation unit is usually costly, the economic analysis should be further investigated to evaluate whether the SOFC system integrated with hybrid vapor permeation-pervaporation process can offer some worthwhile benefit with agreeable investment expenditure.

6.2.3 The final case of using hydrophobic pervaporation having $\alpha_{E/W}$ = 24 incorperated with the SOFC system still shows some available heat emitted to environment. Accordingly, it is recommended that excess heat should be recovered by adding combined heat and power (CHP) cogeneration units i.e. turbine, recuperator to increase efficiency of SOFC system.