Dear editor XXX:

I have received your letter about the comment for our manuscript “Design of Multi-Sensor Fusion Water State Observer for Proton Exchange Membrane Fuel Cell based on Particle Filter” (XXX). We quite appreciate your favorite consideration and the reviewer’s insightful comments. We have made some revision to our manuscript accordingly and we hope the revision will make our paper more acceptable. All the revisions have been highlighted in the revised manuscript.

Please let me know if you and reviewer have any other questions. Thanks again for your and reviewer’s patience, help and constant attention to our manuscript.

Sincerely yours,

**Responses to the reviewers’ comments:**

We highly appreciate the reviewers’ kind consideration of the scientific content of our work. The comments and suggestions made by the reviewers are very helpful for us to revise the manuscript. A detailed reply to the comments and suggestions has been made as follows. (Note: The responses to the reviewers’ comments are highlighted in blue).

**Reviewer: 1**

At the end of section 2, it is said: "Therefore, based on the understanding of the model and the characteristics of the measured data, manually adjust the  
parameters to determine the order of magnitude of the parameters, making the trend of the model reasonable. Then the Parameter Estimator function is used in the Simulink Design  
Optimization toolbox for small-scale parameter optimization."  
The authors should better explain this point. Refering a MATLAB toolbox is not an appropiate justification in a cientific journal.  
What to you exactly tune ? How do you do it ? which cost function do you optimize ?

解释recursive least square estimator algorithm以及在其他研究中的应用(参考文献)

Reply: We adjust the parameters mentioned in Table 1, which contains the oxygen/water diffusion coefficient, water conversion coefficient between membrane and the cathode charge transfer coefficient etc. We use the recursive least square estimator algorithm to minimize the difference from given initial values.

I don't understand section 3. The authors refer to an observer, but what they propose has little to do with what I understand by an observer.

添加多篇(2-3)文献引用,解释observer的意义.

Reply: The observer here refers to the estimation function that takes in sensor data, and produces the estimation.

The authors assume one state is known to estimate the next? How do you know that the initial state is correct?

添加参考文献的引用,说明initial value的正确性.

Reply: For first question, yes, a previous state is required to estimate the current state. For the second question, the initial state value in this paper comes from choosing the set of value that’s closet to actual values, during this process we used heuristic method to choose the best set.

What sensory information do the authors use?

在文章中添加一些描述输入的内容,同时描述不同的观测方法(Observer)方案里使用了哪些数据来源.

Reply: We used sensory data from these sources: The Air pressure on hydrogen/air side, including input & output pressure. Temperature on both sides, including input & output pressure. The system’s power output, and average voltage/current of each cell unit.

Authors should make an effort to properly position their work in the literature. There are various works in the literature that use observers to estimate the state of fuel cells and, from them, the humidity of the membranes. But they are not cited in the references nor are the results compared with theirs.

在Results部分添加和[31,32,33]结果的比较,这篇论文的结果是否在以前文章的结果内,以说明这个文章的结果是否合理,(要列出数字的比较)

Reply: In the introduction section we cited Yuan[31], Nafchi[32] and Farcas[33]’ s work to compare their research with ours.

Reviewer #2: Water management is one of the key approaches to enhance the durability of PEMFC. Therefore, it is necessary to identify the internal water state of the PEMFC accurately and quickly and control it within a reasonable range. The current paper verifies simulation, experiment and the simplified mechanism model of PEM containing water in ionomer, liquid water and water vapor. Based on the simulation, the internal water state trend of the PEMFC was analyzed and can accurately estimate the water state inside PEMFC, contributing to the advancement of PEMFC technology and its wide application in the automotive field. Thus, the work can be considered relevant to the area, so, I recommend the publication to the Energy Conversion and Management after minor revision:  
1) Page 5, Information about reason of choosing certain measurement noise and process noise are missing and needs corresponding literature.

**解释为什么要加入measurement和process noise的数值,以及为什么选择特定的noise和文章中的数量级**

Reply: We introduced Bao’s researches[14, 26, 27] to better demonstrate our selection of measurement noise

2) Page 5, description, and physical explanation of Figure 1 are needed.

在文中解释figure分为哪几个区域,不同区域的界面之间包含了哪些物质的流动

Reviewer #3: Dear Author,  
In order to quickly identify the water state in PEMFC, a simplified model of the mechanism of proton exchange membrane containing water in ionomers, liquid water and water vapor is established. The simplified mechanism model is verified by simulation and experiment. Then, the influence of measurement noise and process noise setting values on the performance of the observer is analyzed. The article has the following features:  
1. A simplified mechanism model of PEM containing water in ions, liquid water and water vapor is established.  
2. Influence of measurement noise and process noise setpoints on observer performance.  
3, noise variance 10-4, process noise 10-8.  
4. Internal state observer based on membrane model and particle filter algorithm.  
5, the change trend of the internal water state is simulated.  
6. The performance of the state observer based on voltage, high frequency resistance and sensor fusion is compared.  
To sum up, the research work presented in this paper is relatively complete, the model verification is highly accurate, and the innovation is strong, which is worthy of publication in Energy Conversion and Management. However, before this, some questions need to be explained:

1-What does the simplified model do? What is the most prominent role of this simplified model in monitoring internal water status compared to existing studies? Can it be put into practical production applications?(问宋博)

这个模型用于计算内部的含水量,这个模型不管把阴极的流道/扩散层进行了区分,同时对不同层级之间的界面用公式进行了定义,因此计算的结果更加准确.

XXX  
2- What are the meanings of online and offline? What is the difference in the measurement process?

Observer:Online,在燃料电池工作时,一边收集数据一边实时计算输出(含水量);Offline,燃料电池工作完成后再计算输出.

Reply: Online estimation can use new data from model during execution, it can capture changes of model instantly and produce better results.

3- The existing measurement method does not distinguish the flow channel, GDL, CL, how did the existing research measure?

(Measurement的具体定义待定)

这篇文章的收集数据的方式和其他文章没有区别,存在区别的是对模型的定义/描述,在观测层面使用了新的sensor fusion的方式.

我们的测量方式同样不区分GDL和CL等,因为实际过程中难以在线测量.因此其他研究的测量方式同样是…  
4- FIG. 5, What was the cause of the sudden change in the average voltage in the 80s?

电压的突然变化,结合图四,是因为空压机的转速和电流的突然变化,同时为什么会先上升下降(转速先拉高,导致电压上升;之后,电流拉高,导致电压下降)

Reply: The model’s estimation performs worse when voltage is unstable, and experiment 3 has unstable voltage.

5- Please explain why Observer-HFR and Observer-Fusion observations of membrane water content and CL liquid water volume fraction are close.

HFR是为了表示含水量,电压可能会因为多种原因导致变化.所以在实验的情况中,sensor fusion和HFR

含水量和HFR之间存在强关联,引用文献说明HFR的变化主要是由膜内含水量的变化导致的,而Sensor Fusion除了HFR之外还包含了其他的信息,因此可能会比HFR更精确的描述水含量. (找寻文献,说明其他的信号也能描述水含量,同时,这种信号也存在于Sensor Fusion的输入中,因此sensor fusion的数据来源里包含了不止一种用于描述水含量的信息)  
Reply: HFR handles higher dimension data better, and Sensor fusion performs better when input data comes from multiple sensors. In this research two methods has similar performance due to the small number of sensors and relatively lower dimension of data. However the sensor fusion method can adapt better with additional sensors whereas HFR methods may lose accuracy due to extra source of data.

Reviewer #4: The long, detailed manuscript presents the development of a sensor for PEM fuel cell based on particle filter. The overall investigation comprises an effective model for the fuel cell, a few dedicated experiments, the methodology used for the state observer, and the results, namely the efficiency of observers relying on different statistical criteria, on some variables (or states) of the fuel cell. The paper seems of high relevance in the domain, the structure of the paper appears appropriate, as well as the illustrations. The language is in overall OK to me, but should nevertheless be improved : (i) some words used in the MS sound not suitable for the targeted meaning ; (ii) the position of adverbs has to be checked and corrected in some places ; (iii) tense of verbs as in section 5. More detailed questions/comments/suggestions are listed below.   
\* Abstract : a couple of concepts mentioned is not straightforward for any reader e.g. « The state online indirect method .. », « sensor fusion ». Besides, is the abstract not somewhat too long ?

压缩到240字以内

Reply: We have removed useless introduction for online indirect method, avoiding ambiguity in the sentence.

把新的Abstract的内容粘贴到这里

\* The list of symbols is of real use in the paper, but a few are missing such as « omega », or « MAPE ».

首先,感谢您提出了这么细致的意见,也很抱歉存在这样写作上的疏忽.我们已经在文章中做了相应的改动.

First of all, we are appreciative of your thorough and insightful critique. Please accept our sincere contrition for the erroneous passage. Guided by your perspicacious counsel, we have meticulously revised the manuscript to rectify the identified inaccuracies. Below is the amended version, duly incorporating the requisite modifications.

TODO: 添加原文

\* Numerical modelling, page 5. The assumptions are given. Does assumption 7 means that the various cells in the stack behave the same, i.e. with the same voltage, the same relative humidity and water pressures at various locations ?

我们的假设的确是所有的cell有相同的电压,

Reply: Precisely, the stipulation in question posits that the multifarious cells comprising the stack exhibit a congruous behavior, exemplified by a uniform voltage. While acknowledging the potential for heightened precision by accounting for cell-to-cell variations, our present endeavor was oriented towards introducing a novel methodology for status observation. Consequently, to streamline the model's complexity, we judiciously presumed a homogeneous voltage profile across all cells within the confines of this particular treatise. However, we concur that incorporating cell-specific voltage could potentially yield more accurate results, an avenue worthy of future exploration.

如果考虑所有cell的电压的情况,可能会产生更好的结果,但本文的意图是提出新的状态观测器方法,为了简化,在本文中做出所有cell有相同电压的假设

\* Section 2.1.2 what does « .. where the size of the surface tangential force is … » mean ?

Reply: In response to your perspicacious inquiry, we have judiciously excised the phrase "the size of" from the manuscript, as it may have engendered unnecessary obfuscation. Indeed, the tangential force exhibits a direct correlation with the gas flow rate or velocity, rendering supplementary elucidations superfluous.

\* Besides, the authors mention vlig in m/s as the liquid flow rate. Why not speak on liquid velocity ?

Reply: Guided by your review, we have revised the manuscript, renaming the parameter in question as "liquid velocity" throughout the entirety of the paper as the more explicit locution "liquid velocity" may foster greater accessibility and comprehension for a broader readership.

\* Rel (13): Could the exponent 4 for variable s be justified ?

Reply: The equation is an empirical equation referenced from Hu’s research[29]. (添加完整的信息(ref list标号后的内容)

\* Below rel. (15), the viscosity has to be « µ ».

Reply: We have removed the typos of extra µ in the equation.

\* Section 2.1.6. « The mutual conversion » : is not it actually a phase conversion rate ?

Reply: It’s a phase conversion state, the article used mutual conversion to better demonstrate the focus on liquid and gas.

\* The description of Schroeder's paradox is interesting, but the explanation sentence should be rephrased.

Reply: We have reorganized the order of explanation for Schroeder’s paradox.

\* Rel. (35) : could the factor 2 for variable s be explained ?

Reply: The equation is an empirical equation referenced from Dullien’s research[37].

\* General comment for a recurrent point : in many places in the paper, the expression of a variable is introduced in an sentence, the expression is given, and followed by « where X is the variable … ». The lengthy, repetive structure could be easily replaced by introducing the expression of variable X (here give its name !) before this expression. Besides, the recurrent expression « is represented as follows » could be (i) improved, and sometimes be rewritten with alternative words.  
\* Does rel. (55) apply for any polysulfonated membrane, in particular for the membrane used in this work ?

Reply: This equation is an empirical equation referenced from Jiao’s work[41]. The parameter of this equation is applied to all PEMs.  
\* Table 1 : could it be specified that the temperature was at 65°C (338.15 K) ?

Reply: We have added extra constraint to table header.  
\* Rel. (62) : what does wk(i) represent ?

Reply: The wk^(i) is used to represent the state of particle in step K, the state wk^(i) is determined by the previous state wk^(i-1)

添加wk的来源和参考文献  
\* Page (19) « measurement noise and process noise ». How are they defined ? How are they generated ?

Reply: The definition and generation of both measurement and process noise were both discussed in Section 5.2

参考Review 2-1的回复  
\* Section 4. Tests consisted in a sudden change in air flow rate (or more precisely in rotation speed of something) and at measuring the cell current and the high frequency impedance. OK, but was it done at a fixed, specified voltage ?

Reply:电压并不是在一个固定的区间,因为因为转速的变化,电压会发生变化.在调整完转速之后,由于电流的增加,电压也会发生降低.

\* Table 4 : What does « CMP speed » mean ?

Reply: We have replaced “CMP Speed” with “Air Compressor Speed” in Table 4.  
\* The presentation of section 5 is not straightforward for a non-specialist of observers, with a couple of not fully clear concepts e.g. « observer fusion », however, it sounds really interesting since based on a solid methodology (just a comment).

Reply: The Observer-Fusion is a simplification for “observer based on sensor fusion”, it’s compared with “observer based on HFR”.

在文中添加Sensor Fusion的解释  
To conclude, the paper could be published after minor revision, most of them for the sake of an easier reading by non-specialists of the topic.