

13 March 2024

Market Operator  
Oman Power and Water Procurement Company  
PC 112, Ruwi  
Muscat  
Sultanate of Oman

## Certification: Market Management System

This certificate is in relation to the Oman Electricity Market Management System (MMS) Scheduling and Settlement calculation software:

- Market Scheduling Software and Settlement calculations within MMS "OPWP ETSE 3.4" software with ETSE version: 3.4.0-20230721\_02, OPWP version: 3.4.0-SNAPSHOT, OPWP revision: ad4c65de6ca053084ce1d41661414a08850aebec, and OPWP build time: 2023-11-29T17:13:16+0100, with configuration parameters as they were in the test environment "TESTO1 - V4.7.20.4.1" on 13 December 2023.

Unless otherwise specified, capitalised terms used but not defined in this letter shall have the meanings given to them, where applicable, in the Oman Electricity Market Rules version 4 (Market Rules) issued on 1 December 2021.

Oman Power and Water Procurement Company SAOC (PWP), in its capacity as the Market Operator operating the Oman Electricity Market which commenced operations on 1 January 2022, has requested an independent certification of the Market Scheduling Software and the Settlements calculations.

Robinson Bowmaker Paul (RBP) was retained by PWP to act as an independent market auditor to review and certify the above Market Scheduling Software; verifying compliance with the Market Rules. While RBP has also reviewed compliance with the Scope of Work (SOW) between

PWP and the MMS supplier, this certificate relates only to compliance with the Market Rules relevant clauses.

## Scope

The MMS performs a number of material obligations set out in the Market Rules, including:

1. Implementing the constrained (mixed integer) optimisation algorithm which commits and schedules facilities (including the derivation of generation quantities to be dispatched by facility in each 30-minute dispatch interval), and forms the System Marginal Price (SMP) (the Market Scheduling Software)
2. Calculating various settlement quantities that enable the derivation of amounts payable to Generators, and receivable from Generators (the Market Settlement Software)
3. Performing certain pre-processing and aggregation functions to prepare input data for use in the Market Scheduling Software and the Market Settlement Software.

Parts of the MMS that are not included in the scope of this certificate include the following:

- The Market Trading Software which is the participant interface which facilitates offer and data submission, and other administrative functions. The functionality of the Market Trading Software is outside the scope of certification, as User Acceptance Testing is the more appropriate means of testing such a system.
- The testing of interfaces between systems is out of scope.
- Usability, speed, security, or any aspects of software performance other than the correctness of the calculations performed.

## Certification review methodology

In reviewing the formulation and software, we have:

1. Identified relevant calculations set out in the Market Rules;
2. Reviewed PWP documentation pertaining to the function of the software;
3. Identified test cases required to confirm compliance;
4. Created input data for the test cases to ensure that the required scenarios are covered;  
and
5. Verified that the test inputs and outputs together demonstrate that the calculations do or do not comply with the Market Rules.

Our review was designed to provide reasonable assurance as defined by International Standard on Assurance Engagements ISAE 3000 "Assurance engagements other than audits or reviews of historical financial information" issued by the International Auditing and Assurance Standards Board.

## Caveats

This certificate is subject to the following caveats:

1. Input data – This certification assumes that all input data received by the Market Scheduling Software and the Market Settlement Software has been entered correctly and is consistent with specifications. This includes, but is not limited to, data passed from the Market Trading System to the Market Scheduling Software and the Market Settlement Software, and data passed from the Market Scheduling Software to the Market Settlement Software. Such data will have passed through various validations within the Market Trading System. For example, we assume that Generator offers are compliant with the Market Rules and consistent with the Generator's technical data such as Transition times and costs.<sup>1</sup>
2. MIP<sup>2</sup> Gap Tolerance – the Market Scheduling Software includes a user-defined parameter that sets the maximum 'MIP Gap', which is the difference between the upper and lower bounds on the Objective Function Value that are discovered during the solution process. When the MIP Gap is within the MIP Gap Tolerance, the software will stop searching for better solutions and consider the best solution found to be 'close enough' to the optimal solution. In our certification testing, which mostly uses small, simplified data sets, we set the MIP Gap Tolerance to 0.01%. In solving the full market system, a setting of 3% has been used. We have not analysed the impact of this parameter setting in the market. We recommend that PWP uses the lowest setting that is practical for obtaining a solution within an acceptable timeframe.
3. Post-processing of the System Marginal Price (SMP) – It may not always be possible for the Market Scheduling Software to produce an SMP that is entirely consistent with clause L.2.2.1 of the Market Rules. This clause requires the SMP to be the marginal cost of incremental demand. The SOW recognises the difficulty of marginal pricing in a complex, multi-period Mixed Integer Program (MIP) algorithm such as is used in the Market Scheduling Software and allows for post-processing to ensure that the SMP correctly reflects the incremental marginal cost to the extent that this is possible. The MMS

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<sup>1</sup> In the test environment we observed issues within the Market Scheduling Software when Generator offers passed into the Case Module were found to be out of order and otherwise incorrect which resulted in non-monotonically increasing offers, which means that the optimisation is not possible. The Case Module is not used in any market runs, but only for testing and investigations, hence this is not within the scope of this certificate. It should also be noted that we did not observe any such issues with offers passed into the Settlement System.

<sup>2</sup> Mixed Integer Programming

supplier has not provided a description of the post-processing algorithm that has been implemented in the MMS, therefore we have not directly tested this algorithm but have based our methodology on comparisons of the resulting final SMP with our expected SMP in each test case.

The complexity of the Market Scheduling Software means that there may be situations when the only way to ensure that the SMP reflects the incremental marginal cost would be to rerun the software for each of the 48 Trading Periods with a small increment in demand, however, even this may not produce a suitable SMP, where the MIP Gap Tolerance setting allows for a non-optimal solution, a different solution to the original may be found in the rerun. Additionally, conducting such reruns may not be practical in the time available.

In some of our test cases, all of which involved situations that would, in the real market, be either not possible or highly unlikely to occur, the SMP reported by the MMS did not match our expectations.

Given the low probability of these situations occurring in practice, combined with the practicality of conducting multiple reruns to ensure the SMP reflects the actual cost of an increment in demand, we find the post-process determination of the SMP in the MMS to be acceptable. Nonetheless, we recommend that PWP seek explicit documentation of the post-processing calculations used to determine the SMP in order to have a complete understanding of how this has been implemented, and that, when obtained, and if appropriate, further verifications could be conducted based on the provided documentation.

4. Market Rule Update – The equation for Market Schedule Production Cost (MSPC<sub>bd</sub>) in Market Rule L.3.3.5 needs to be updated. The second occurrence of the term  $ROAP_{iuh}$  contains the index  $i$ , but is not included in any summation over  $i$ . This term should be indexed by  $h$  instead. The MMS software appears to be performing the correct calculation according to the intent of the rules. The Market Rules need to be modified so that they are consistent with the software implementation.
5. Undocumented functionality in energy settlements calculations – Our testing revealed that there is undocumented functionality in the MMS energy settlements calculations: If the Market Schedule Availability (MSA) is less than the unit's MINOUTPUT value, then the MINOUTPUT value is reduced to be equal to the MSA. This can have a material impact on the calculation of the MSNLC value. PWP have decided to update the Market Rules to include this functionality. Until the associated Market Rules change process is complete,

the MMS Settlements software is noncompliant with the Market Rules in this respect. However, the MMS Settlement software is generating the intended results.

6. MMS version control – Our testing has shown that MMS functionality, including Market Scheduling and Settlements calculations, can be altered materially without changing the software version number. This can occur because significant portions of the MMS functionality are determined by configuration parameters, which can be modified without releasing a new software version. Consequently, this certificate is only valid for the software version and set of configuration parameters that were present on the testing environment on the date specified in the version below. To ensure that the opinion set out below remains valid, PWP will need to implement a robust set of controls to ensure that the configuration parameters are not altered without a complete set of regression tests being successfully run on the resulting system.

## Opinion

As a result of our examination of the Market Rules and our testing of the MMS software, we are able to provide the following certification:

*Subject to the qualifications listed in the previous section, we certify that:*

- *The relevant calculations performed in the Market Scheduling Software and Market Settlements Software within MMS "OPWP ETSE 3.4" with ETSE version: 3.4.0-20230721\_02, OPWP version: 3.4.0-SNAPSHOT, OPWP revision: ad4c65de6ca053084ce1d41661414a08850aebec, and OPWP build time: 2023-11-29T17:13:16+0100, with configuration parameters as they were in the test environment "TESTO1 - V4.7.20.4.1" on 13 December 2023, comply with Version 4.0 of the Market Rules, dated December 2021.*

## Limitation of Liability

This certificate has been prepared by RBP for PWP based on information supplied by PWP. To the maximum extent permitted in law, RBP excludes all liability to any other persons for any loss or damage, whether direct or indirect and however caused (including through negligence) that may be suffered because of reliance on this opinion by that third party.

Should you wish to discuss the matters raised in this certificate further, please do not hesitate to contact me.

Yours sincerely,

A handwritten signature in black ink, appearing to read "R. Bowmaker". The signature is fluid and cursive, with a long horizontal stroke extending to the right.

Richard Bowmaker

Principal