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Protocol for Uniformly Measuring and Expressing the Performance of Energy Storage Systems

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June 2014

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Foreword

The *Protocol for Uniformly Measuring and Expressing the Performance of Energy Storage Systems* (PNNL-22010) was first issued in November 2012 as a first step toward providing a foundational basis for developing an initial standard for the uniform measurement and expression of energy storage system (ESS) performance. Its subsequent use in the field and review by the protocol working group and most importantly the users' subgroup and the thermal subgroup has led to the fundamental modifications reflected in this update of the 2012 Protocol. As an update of the 2012 Protocol, this document (the June 2014 Protocol) is intended to supersede its predecessor and be used as the basis for measuring and expressing ESS performance. This foreword[1] provides general and specific details about what additions, revisions, and enhancements have been made to the 2012 Protocol and the rationale for them in arriving at the June 2014 Protocol.

Dynamic Updating Process

Because energy storage technology development and application are dynamic and the technologies, and the metrics and applications covered in the protocol continue to evolve, the provisions in it will evolve to more fully address the wide scope and purpose stated in Sections 1 and 2 of the protocol. For instance, further enhancements will be made to allow the protocol to be used to address photovoltaic smoothing applications later in 2014. The dynamic nature of storage technology supports continual and ongoing work to enhance the protocol. The need for uniformity and comparability of the reported performance information for all storage technology suggests that the protocol will need to be revised and republished at reasonable intervals.

Standards are generally updated and revised on a 3- to 5-year cycle and, in some cases, interim addenda covering needed revisions or enhancements to the base standard are also issued. At some point in the future, this protocol will provide a foundational basis for initial standards development. Once the related standards are completely developed and available, the protocol review/revision effort will likely evolve to providing recommendations and supporting research for subsequent standards updating. Until the standards are completed and published, this document and future versions of it will provide a single basis for measuring and expressing system performance. The intention is to continuously enhance the protocol based on stakeholder input, while also being sensitive to the need for some continuity. Hence, the protocol is expected to be updated at least semi-annually or more frequently if warranted. The updating process will include a cutoff time after which additional revisions will be deferred to the next revision cycle. Work on the deferred revisions will continue, but publication of an updated protocol will occur no more frequently than annually.

[1] The information presented in this foreword is not part of the protocol. It is merely informative and does not contain requirements necessary for conformance with or use of the protocol.

Protocol Enhancement Overview

The interim enhancements contained in this document are based on three concurrent activities. One activity involved the thermal storage subgroup whose members are focused on thermal storage systems and whose efforts are focused on how to more effectively address thermal storage systems for peak-shaving applications. The original 2012 Protocol covered peak-shaving applications but initially focused on all electric systems, so enhancements were needed to address thermal storage systems. Another activity involved the protocol users' subgroup, whose members agreed to "test drive" the 2012 Protocol and provide feedback about their experiences to help refine the performance measurement and expression criteria to make them easier or less time consuming to apply, enhance the accuracy of the results, and/or ensure that the metrics are equally applicable to all systems (e.g., do not support one system type over another). The third activity involved a micro-grid subgroup that developed criteria for the protocol that would ensure it could be used to address the performance of micro-grid energy storage systems in an islanded application. In addition, the protocol working group (e.g., all interested parties that have advised Pacific Northwest National Laboratory of their interest in this activity) was apprised of these efforts and invited to participate by submitting suggested changes to the 2012 Protocol. The collective input received from these three subgroups and the entire protocol working group is the basis for this document. The sections below provide an overview of the protocol enhancements and, where considered crucial, the background for them.

Items Addressed Throughout the Document

The need for clearly defining electrical and thermal energy was raised while including thermal energy storage to ensure consistency in how the document refers to what is measured and reported. Input to the ESS at any instant is power ($V \times I$) and cumulative input to the ESS over time is energy ($V \times I \times t$). Similarly, output from the ESS at any instant is power and cumulative output from the ESS over time is energy. As a result, when addressing inputs to or outputs from the ESS throughout the protocol, those terms are used as applicable. Where necessary, because the criteria specifically refer only to electrical or thermal systems, the terms electrical or thermal are used to qualify power or energy.

Section 1.0

The purpose of the 2012 Protocol, defined in Section 1.0, was specifically intended to be broad so that it did not have to be revised each time additional work was undertaken. Considering the dynamic nature of ESS and the amount of possible work to be done, the purpose establishes a vision that should ideally never need revision. Rather, over time, the protocol will be enhanced to "fill out" the vision as it is expressed in the purpose statement.

In reviewing the purpose to ensure it addresses thermal storage, one word in the purpose—"individual"—was identified as needing additional consideration because it could be confusing and limit the purpose. The word "individual" provides for the consideration of each ESS separately but not in the aggregate. Consider the situation where two systems operate as a "team." If the user wanted to draw the system boundary around multiple individual systems and consider them a single ESS for the purpose of assessing the performance of the aggregate, the purpose as presented in the 2012 Protocol might not provide for the boundary to be drawn to include all of those systems in the aggregate. The deletion of "individual" from the second sentence supports the broader application and use of the protocol, at least in the governing purpose statement for the document. The purpose now clarifies that the protocol can be used to address multiple individual systems that are interconnected and operate as one ESS if the user so chooses to consider them as interconnected as one ESS.

Section 2.0

The scope has been revised as suggested to delete the permissive (e.g., may) inclusion of the battery management system (BMS) and simply include the BMS as part of the ESS. As such, the system includes the storage device, the BMS, and any power conversion systems installed with the ESS. The intent of the scope is to ensure that the ESS includes not just the storage technology itself but all the other components, controls, etc. associated with the ESS that allow it to perform its intended function. That said the scope is also intended to be limiting so that specific items beyond those described in the scope, such as a building or building components, are not included in the ESS. This revision should help more clearly establish what is and is not included in the ESS. Without a specific indication of what is included, it would be difficult to compare performance results obtained by different users.

One stakeholder suggested that the term "includes" be changed to "consists of." The comment focused on the need to specifically define what constitutes an ESS and the phrase "consists of" would introduce a complete list of all components that would be included in the ESS. The phrase " consists of" is very specific (e.g., just this and nothing else), whereas "includes" is less specific and restrictive; the latter establishes as a minimum what must be included, but allows other components not listed to be included in the ESS as well. Considering that the protocol is relatively new and there is no single, agreed-upon definition of an ESS, it seems more reasonable to retain the term "includes" to establish a minimum as opposed to using "consists of," which is more definitive and specific. As the industry evolves and standards are developed for ESS, it is likely this issue will be discussed in greater detail and addressed more formally through standards.

Section 3.0

Definitions were added, deleted, and revised in this document.

- A definition of **power factor** has been added to address a comment that power factor be included as a metric in the protocol. (See discussion below on how power factor is to be measured and reported.)
- The definition of **power performance** has been revised to apply to electrical power, and a new definition for **thermal power performance** has been added to address the application of the protocol to those systems.
- The definitions of **ramp rate**, **reference performance test**, **roundtrip energy efficiency**, **response time** and **stored energy capacity** have been revised and enhanced to better align with changes made to the testing-related sections in the protocol associated with those terms.
- The definition of **energy performance** has been deleted because the term is no longer used in the text of the document.
- A definition of **islanded microgrid** has been added to address the new application of the protocol to islanded microgrids.
- A definition of **microgrid** has been added to address the new application of the protocol to islanded microgrids and was based on the definition from the Microgrid Exchange Group.

Section 4.0

The provisions in the protocol overview section were revised to add the weight, volume, and footprint of the ESS to the information the manufacturer is required to provide in the description of the ESS. While not directly relevant to ESS performance, it is recognized that at this point in time there may be no recognized document that outlines the minimum specifications to describe an ESS. Until another document listing a proposed minimum set of ESS specifications is available, including these items in the protocol is intended to provide much-needed guidelines.

Additional text has been added to address a situation where the system is not “unitary” or a “matched assembly of components” and as such does not have a single manufacturer who is in the position to provide this information for the entire system. When an ESS is made up of separate components put together by a system integrator or designer/installer, there is technically no ESS manufacturer, but that designer/installer is the entity who must apply the protocol in describing the ESS boundaries. This additional text clarifies the responsible party throughout the document. While “manufacturer” is used throughout the protocol to assign responsibility for items of this nature, this change is intended to convey that the “designer/installer” may also be the manufacturer depending on the manner in which the system is designed, assembled, and installed. This is further covered in Section 4.3 wherein the identification of the ESS application is to be made by the manufacturer if there is a single manufacturer and if not then the application of the ESS is designated by the system integrator. Clearly, if the ESS is not made by a single manufacturer then the “manufacturer” is the designer who is putting together the ESS by integrating a number of separate components and devices.

Metrics for peak-shaving applications have been revised as follows:

- Capacity is now referred to as stored energy capacity.
- Ramp rate has been included as a new metric.
- Energy capacity stability has been included as a new metric.
- Power factor has been included as a new metric.

Metrics for frequency-regulation applications have been revised as follows:

- Capacity is now referred to as stored energy capacity.
- Energy capacity stability has been included as a new metric.
- State-of-charge (SOC) excursions has been included as a new metric.
- Power factor has been included as a new metric.

The initial protocol covered peak shaving and frequency regulation applications. Enhancements to the protocol now provide criteria for its use in measuring and expressing the performance of ESS for another application, which was operation of a microgrid in an islanded mode. A typical microgrid is connected to the main grid, and should have the flexibility to operate in an islanded mode. Since the applications associated with a microgrid while connected to the grid are quite large in number, the microgrids sub-group focused on operation of an ESS in an islanded mode. The metrics for an islanded microgrid application are the same as those for frequency regulation applications.

The following use cases for an islanded microgrid application were considered and are included in the protocol:

1. Microgrid with Renewables (where renewables consisted of a mix of solar and wind generation)
2. Microgrid with Renewables but no frequency regulation
3. Microgrid with no renewables and no frequency regulation

Additional criteria have been added to clarify that the application of the protocol is limited to assessing the performance of the ESS, or multiple ESS that are interconnected, within a defined building or facility boundary. If more than one ESS is connected directly to each other electrically, a boundary can be drawn around all the connected ESSs to define the integrated ESS. However, if the ESSs are at multiple locations and are not electrically connected to each other directly but are interconnected through the grid, such separate ESSs cannot be considered in the aggregate. While this issue was not raised during the development of the 2012 Protocol, the consideration of thermal storage systems, wherein systems located in multiple buildings could be considered in the aggregate, necessitated additional clarification. Having determined the performance of any ESS, electrical or thermal, through the use of the protocol, the performance of any number of different systems that are interconnected through the grid and spread across multiple building and facility boundaries (e.g., decentralized systems) could be addressed through additional calculations. Such calculations are outside the scope of this protocol, but the performance information acquired by using this protocol on each separate ESS can be combined with the performance information for other ESSs and used to calculate the performance of such a decentralized storage system (i.e., one can calculate the performance of the whole based on the individual performance of the pieces).

The original intent when developing the 2012 Protocol was to apply the provisions in the protocol for peak-shaving applications equally to electric and thermal systems. When revising the protocol to specifically address thermal storage systems, it was initially suggested that a new separate path and criteria unique to thermal systems for peak-shaving applications be considered. Input from the thermal subgroup about a separate path for thermal systems focused on the meaning of application classification (in Section 5.1.1 of the protocol) and whether thermal systems would need a different classification scheme. If all systems—electric and thermal—are to be treated the same and comparisons between them addressed, then it was determined that those for peak-shaving applications would have to be classified under the same criteria. It was decided to retain the single path approach and set of criteria for all systems for peak-shaving applications in the 2012 Protocol to allow all such systems to be compared on the same basis. The alterative would have resulted in electric ESSs being assessed and compared based on different criteria than thermal ESSs so that only electric systems could be compared with other electric systems and thermal systems compared with other thermal systems.

One desired outcome is the ability to compare all systems intended for peak shaving on the same basis, which requires the application of a single duty cycle. The duty cycle for peak-shaving applications in Section 5.1.3 has been revised to be less onerous, as discussed below in Section 5.0, and now applies to both electrical and thermal ESSs.

Section 4.5 was initially written in 2012 to allow the protocol to be used for all electric systems. As such, there was no need to address the issue of equating energy use associated with different forms of energy. The inclusion of thermal storage systems as discussed above resulted in Section 4.5 being revised to further clarify how the single path for assessing all systems used for peak shaving will flow through data acquisition, use, and reporting. A single path means that any system, regardless of energy storage as electrical or thermal, would be subjected to the same tests, same data acquisition, and same use of the data in arriving at performance results. If all the data are in a single unit of measure such as kilowatt-hours then they need not necessarily be converted to another unit of measure. If there are multiple energy forms involved, then data may be in different units and may need to be converted to consistent units to derive the performance results. The revisions contained in this section of the protocol are intended to clarify the intent of the protocol in this regard and reference an existing standard that can be used as the basis for such conversions.

American National Standards Institute/American Society of Heating, Refrigerating and Air Conditioning Engineers (ANSI/ASHRAE) Standard 105-2014, provides a methodology for measuring and expressing the energy use of a building. Standard 105 is not a test standard but simply a standard methodology for taking the simulated or actual energy use of a building and using the values to report the performance of the building. It provides for establishing a boundary across which energy flows and then how to equate the various energy flows across that boundary. It addresses energy use within a building in terms of measured energy across the boundary in the units measured, their conversion to and combination as site British thermal units (Btus; measurement where energy use occurs) and also as source Btus (consideration of any energy associated with generating, transmitting, or distributing energy to the point of use). The same approach is considered applicable for ESSs by simply considering the boundary as that of the ESS as opposed to a building. This provides the needed basis for the conversion and combination of different energy forms into a single value, which in turn allows for the performance of electrical and thermal systems to be presented on an equivalent basis.

One stakeholder requested that the protocol address measurement and reporting of voltage and temperature across ESS cells or modules. This request was intended to address inquiries for such information from manufacturers and provide a basis for the comparability of any reported values. As noted above, the focus of the protocol is to address the system and what is input or output across that system boundary. What occurs within the system, whether related to system performance or not, was specifically omitted from the scope of the protocol. This was because others were working on system components and there was no effort underway to address system performance. After deciding to focus on the gap and address only the ESS, time and resource limitations suggested the initial focus needed to be on metrics key to system performance. The operating temperature and voltage across segments within the system is outside the scope of the protocol. That said, because there is no other vehicle for addressing this or other informational needs, text has been added to Section 4.6 that establishes a basis for going above and beyond what is required in the protocol. Specifically, the measurement and reporting of other information not specifically required by the protocol is allowed and when a decision is made to do that the revised text provides that the information and the basis for that information be reported on the ESS label required by the protocol or in the ESS manufacturer's specifications. This provides a vehicle, but not a mandate, for the manufacturer to self-designate what additional information it wants to provide at the system level or within the system, and the basis for that information. In addition, it provides the basis for ESS users to define any additional information they desire, reference it in the documents through which they will procure an ESS, and through that activity move ESS manufacturers to provide the additional information.

Section 5.0

In the section on applications, comments were received suggesting further specificity of the conditions to be applied in determining system ratings as covered in Section 5.1.2 and to also address the issue of system service life. For complete comparability of system performance information, system ratings should be based on standardized operating conditions such as temperature, humidity, etc. Standardizing the conditions would further ensure an accurate comparison of the performance of different ESSs. There was insufficient data available when the protocol was written and during this revision to the protocol to address this comment. In addition, the establishment of a single duty cycle was considered the priority when writing the 2012 Protocol to ensure some reasonable level of comparability of reported ESS performance. The specification of the ambient operating conditions should be addressed in the future. In an attempt to address this issue, the revisions further refine the provision that the operating conditions under which the tests are conducted be the specific ambient operating conditions specified by the manufacturer. This at least ensures that users considering ESSs have consistent performance information pursuant to the protocol, including the ambient conditions under which the performance was measured. The last sentence of the first paragraph of Section 5.1.2 in the 2012 Protocol was an attempt to speak to the issue of ESS durability and service life. As noted above, this was raised as an issue, but no specific text or methodology was proposed to address the issue. This could be addressed in the future either through the metrics measurement subgroup or through a new protocol effort focused on service life and reliability.

Members of the users' subgroup that applied the 2012 Protocol to a peak-shaving application of ESS had significant comments about the duty cycle described in Section 5.1.3. Specifically, it was too long (seven days), and compared to a shorter duty-cycle time frame it did not appear to provide commensurate increases in data accuracy or reliability. Based on input received, the duty cycle now comprises the original three duty-cycle segments, but they are now implemented in series over a total time period of only 3 days (one day per segment). The text describing the duty cycle, charge window, float window, and discharge window has been revised to provide additional clarity and facilitate its application and use. This was in response to users' subgroup input indicating that the language covering how to actually implement the duty cycle was not clear.

One question was asked concerning the need to measure any auxiliary energy provided to the ESS during the test and include that in the assessment of the performance of the ESS. The additional clarifications added to the text describing the application of the duty cycle address this issue without having to specifically speak to any energy use for auxiliary systems. Regardless of the location of the auxiliary systems, energy input to the ESS is measured during the charge window, then the ESS floats (e.g., no charge or discharge), and then the ESS is discharged. Any auxiliary energy is inherently included, whether during the charge window as energy needed to bring the ESS to its maximum SOC level or when measuring the discharge energy output of the ESS when it is brought to its minimum SOC level. A radical example would be taking an ESS to its maximum SOC level and then during the float window using all of the stored energy for auxiliaries in the system, resulting in the amount of energy measured during the required discharge window as zero.

As discussed above, the performance metrics in Section 5.1.4 have been revised and enhanced, as follows:

- Round trip efficiency (RTE) has been moved to appear first, followed by duty-cycle roundtrip efficiency. Note that the latter has been clarified to apply to the ESS as a function of discharge power.
- Ramp rate is a new metric for peak-shaving applications and is included with response time.

- A new metric has been added to provide for the determination and reporting of energy capacity stability. This is the stored energy capacity divided by the initial stored energy capacity determined before and after the duty cycle. As discussed later under Section 8.0, this is intended to address the capacity stability of the ESS over time, wherein the stored energy capacity can be measured at any time during ESS service life and from that the capacity stability reported. It would be assumed that the initial capacity stability of a "new" ESS would be one or very close to one because the measurements are made at basically the same point in time.
- A new metric has been added for power factor. One member of the users' subgroup felt that because the information for determining the power factor of an inverter that is part of the system is readily available it should be determined and reported.

Similar to the peak-shaving discussion above, comments were also provided about the duty cycle and metrics associated with frequency regulation. One comment suggested replacing the current duty cycle based on the balancing signal from PJM for the year 2011 with a more current PJM signal. Others suggested deleting the PJM signal and replacing it with other signals or simply allowing the user to choose any duty cycle and simply report which one was used when reporting the ESS performance results. A foundation of standardization with respect to methods of testing is to subject the technology being tested to identical conditions. The lack of a common duty cycle results in the inability to reliably compare the performance of different ESSs. With respect to using a more current PJM duty cycle, the issue of frequency of change comes into play. That is, where provisions in a method of testing are changed too frequently, the ability to compare ESS performance over time is also hampered. For the time being, because the protocol is just beginning to be applied, it was considered more appropriate to retain the current duty cycle. That said there are compelling reasons for allowing an updated PJM signal or any other duty cycle to be applied because the application of alternatives fosters gaining experience with them; one of them might be preferable to the current duty cycle. In addition, users of ESSs may desire performance information based on a different duty cycle. To foster the consideration of alternative duty cycles, this document contains a new provision in Section 5.2.2 that provides for the manufacturer to apply one or more additional duty cycles, assess the performance of the ESS against any additional duty cycle, and report the required performance results under an "alternative duty cycle" designation. As such, users of the protocol and users of ESSs will have a standardized and comparable set of ESS performance information. Beyond that, they can also exercise this new approach to determine or request one or more additional sets of ESS performance information developed through the use of alternative duty cycles.

As discussed above, the performance metrics in Section 5.2.4 have been revised and enhanced, as follows:

- RTE has been moved to appear first followed by duty-cycle roundtrip efficiency, a metric that was not in the 2012 Protocol for ESSs serving the frequency regulation application.
- Ramp rate has been combined into response time and the text revised to align with a new test protocol as discussed below.
- A new metric has been added to provide for a determination and reporting of SOC excursions (maximum and minimum).
- A new metric has been added for power factor, as was added for peak-shaving applications.

Provisions have been added to cover an islanded microgrid application for an ESS. For the islanded microgrid, each use case involves storing some excess energy and providing it when needed. All of the use cases include serving critical loads, VAR support, power quality, frequency response and black start. The critical load was assumed to be 25% of peak load, and was assumed to be serviced by the gensets available. The maximum generation from each of solar and wind sources was assumed to be 35% of peak load. While the power capacity of gensets as a percentage of critical loads may vary, along with the power capacity of renewables, this was used as a starting point for a typical islanded microgrid. The working group discussed addressing some other use cases such as modeling, life and safety. Modeling, while considered important, was not considered as a use case, and hence was outside the scope of this work. It was also agreed that the work scope would not include determining failure mechanisms for the ESS. Periodic capacity tests were considered to be a good proxy for the state of health of the ESS. All safety related issues were considered outside the scope. Duty cycles were developed for an islanded microgrid based on this approach. Three different use cases for islanded microgrids were considered, and a corresponding duty cycle for each was developed:

- Microgrid with renewables included in the generation assets (where renewables consisted of a mix of solar and wind generation) and frequency regulation
- Microgrid with renewables but with no frequency regulation
- Microgrid with no renewables and no frequency regulation

The required genset capacity was calculated for all three use cases, based on an assumed roundtrip efficiency of the ESS of 80%. Energy storage sizing in terms of energy and power capacity was determined for all three use cases. Additional generation capacity needed for the genset to maintain the capacity to supply critical loads based on an assumed failure of 25% of operating gensets was determined, along with the ESS energy capacity needed to maintain power for 20 minutes until the backup generators were online.

The rated power of the ESS was set to the maximum charge or discharge power, excluding VAR support, power quality, and black start. This was because the duration and frequency of these use cases was very small, and as a result their inclusion would overestimate the ESS capacity required. More details of the calculations that form the basis for the islanded microgrid duty cycles are provided in the report, "Determination of the Duty Cycle for Energy Storage Systems Integrated with a Microgrid," PNNL-23390.

Section 6.0

Only one change has been made in the section about ESSs. Provisions have been added to Section 6.1 that address the situation, as discussed above under Section 4.0, where there is no ESS manufacturer but instead a system designer/installer who builds a system from components manufactured by different entities. That is, the ESS is not unitary nor is it a matched set of components made available from a single manufacturer. Section 6.1 covers the identification of all subsystems and major components comprising the ESS (e.g., schedule) and this addition simply ensures that where there is no system manufacturer that the designer/installer is responsible for providing this information for the system. (Note that the information needed would be acquired from the manufacturer of each of the subsystems or components that make up the ESS.)

Section 7.0

The provisions throughout Section 7.0 provide the specifics associated with the test methods and procedures to be used in determining the values for all the ESS performance metrics identified in the protocol. Revisions and enhancements were provided primarily by members of the users' subgroup pursuant to the application of the 2012 Protocol to actual ESS technology by members of that subgroup.

The capacity test in Section 7.3 has been clarified as being a stored energy capacity test, which measures the energy capacity of the ESS. In addition, the text has been revised to ensure that this test is clearly applicable to ESSs storing electrical or thermal power. The overview of the test in Section 7.3.1 has been clarified. For instance, the terms "minimum storage level" and "full state of charge" have been replaced with "lower "and "upper state-of-charge limit." One additional clarification is the frequency at which measurements are made during the conduct of the stored energy capacity test. The 2012 Protocol addressed this by allowing the manufacturer to determine the intervals at which measurements would be taken and those intervals documented by the manufacturer to be considered adequate. Adequate is a subjective term and when used can adversely affect the comparability of ESS performance information. Unfortunately, at this time there are insufficient data available to allow specifying those time intervals in the protocol. That said, an improvement has been made to the protocol wherein the manufacturers must now provide information documenting the statistical validity of the time intervals they have chosen (e.g., more definitive and defensible than adequate).

The stored energy capacity test routine has been enhanced to also address thermal systems, both with and without phase change. The ESS is still discharged to its lower SOC limit (as noted above this was previously presented as minimum SOC) and measured. To address electrical and thermal systems the measurement is now the minimum V for electrical, T for thermal without phase change, and P for thermal with phase change, where P is the mass percent of the appropriate phase. The portion of the test associated with charging has similarly been revised, with the energy input necessary to get the ESS to its upper SOC limit measured directly during charging. After this test the 2012 Protocol required leaving the ESS in a 30-minute standby state. Some users indicated that 30 minutes was not a good indicator of how their ESS operated; some suggested a range of 10 to 30 minutes and some suggested having no standby state and allowing immediate discharge after the charge. To allow this test to be applied to different systems and for consistency with changes made in Section 7.4.2 discussed below, the standby time is now "at least 10 minutes but not more than 30 minutes" and the manufacturer decides the time within this range that the system is left in the standby state during this test. The intent of this test is to run through a series of identical discharge and charge cycles and to use the results for energy input and output measurements to determine how much energy the ESS will store. The 2012 Protocol indicated that this testing was to be done at least eight times. Input from members of the users' subgroup indicated that the additional accuracy gained did not justify the time and cost associated with running the test that long. To address this issue the protocol has been changed to require at least two test cycles.

The RTE is determined in accordance with Section 7.4.1. The test has been enhanced to specifically apply to electrical and thermal systems. The data used to determine RTE are still derived from the stored energy capacity tests covered in Section 7.3.2. In accordance with the previous discussion of stored energy capacity, the RTE can now be determined for thermal systems as well.

Section 7.4.2 of the 2012 Protocol addressed duty-cycle roundtrip efficiency for both electrical and thermal ESS. Based on input from the users subgroup and the need to address thermal storage systems for peak-shaving applications there are now two separate subsections for duty-cycle roundtrip efficiency. Section 7.4.2 applies to ESSs for peak-shaving applications and a new Section 7.4.3 applies to ESSs for frequency-regulation applications. Each applies the applicable duty cycle provided in Section 5.0 and, as discussed above, the duty cycle for peak-shaving applications has been revised. For peak-shaving applications, the revisions are primarily focused on ensuring that thermal systems can also be evaluated. The duty-cycle roundtrip efficiency for frequency regulation applications is generally identical to that set forth in the 2012 Protocol. One addition to the test is that after charging and bringing the ESS to the desired SOC it is to be held at that voltage for at least 10 but not more than 30 minutes before the ESS is subjected to the duty cycle. After the duty cycle and charging the ESS back to the initial SOC, it again is to be held at that voltage for at least 10 but not more than 30 minutes. The duty-cycle roundtrip efficiency is still based on dividing the energy removed during the test by the energy required to recharge the ESS. One new provision requires the ESS management system to track the maximum and minimum SOC during the duty cycle by integrating the current over time.

The modification of Section 7.3.2 to address thermal systems with and without phase change was challenging for a number of reasons. For instance, for cold storage the maximum temperature (T_{max}) and minimum temperature (T_{min}) are not intuitive where maximum is a colder temperature than minimum. The application of T_{max} in Section 7.3.2 for cold storage is the temperature of the storage medium at maximum SOC. This ensures there is no restriction on T_{max} being greater than T_{min}. When determining maximum SOC where a phase change material is used in cold storage, the manufacturer of the system will need to determine whether the ice storage is fully charged or fully discharged based on the heat transfer phenomena related to making and using ice and the geometry of the ice storage container. The terminology P_{max}, where P is mass percent (in the case of ice) at maximum state of change, has been included in Section 7.3.2 because an ice/water mixture can exist with a 32°F temperature only at the ice/water boundary). For instance, when the temperature in the water bath rises above 32°F and the ice is gone there will be some upper temperature bound when the SOC is declared to be zero, even though the system could still provide cooling as a cold-water reservoir up to some higher temperature. In applying the protocol to such systems, it would be up to the ESS manufacturers to establish that upper operating temperature at which they consider their system unable to provide cooling. Some manufacturers could use the ESS as purely phase change, in which case the temperature would always be at 32°F, while others could use heating and cooling of the single phase (in this case water). The application of Section 7.3.2 for such systems is to use T_{min} to denote the temperature at the minimum SOC and T_{max} as the temperature at the maximum SOC, recognizing that T_{max} will always be lower than T_{min}.

Another challenge related to cold storage is how to measure the mass percent of ice for a given volume of the ice-water mixture and who reports it. Measuring the level of ice/water would allow determination of the percentage of ice based on mass or volume. Measurement of temperature is straightforward, with strategic placement of a thermocouple in the thermal storage material. What is contained in Section 7.3.2 for cold storage is considered reasonable for now given this new application of the protocol to thermal storage systems. After application of the protocol in the field, the protocol can certainly be enhanced in the future based on stakeholder field experiences.

Measurement of power to charge a cold-storage ESS is based on the power supplied to the chiller and pumps to make ice. Discharge power out is the rate of cooling of the warm air by the ESS fluid in energy units/time, and hence includes consideration of all associated heat exchanger losses as part of ESS losses.

The provisions in Section 7.4.3 covering reference signal tracking have been clarified and enhanced. A time rate of measurement has been included that refers to measurements being taken at each point in time the ESS receives a change in the balancing signal. The 2012 Protocol does not provide sufficient detail about how percentage tracked with respect to the ESS tracking with the signal is to be determined.

Further specificity is now provided on this issue by indicating that when |(Psignal-Pess)/Psignal| is less than 0.02 the ESS is considered to be tracking the signal.

Section 7.5.1 in the 2012 Protocol covering the ramp rate test has been deleted and the details associated with conducting this test have been included in the section covering response time. Section 7.6 covering response time in the 2012 Protocol is now Section 7.5 and covers both response time and ramp rate testing. Figure 7.6.1, depicting the response time test, has been redrawn to provide additional specificity and clarity. This was done in response to questions from the users' subgroup concerning how to interpret and apply the figure in conducting the response time test. Another reason for combining the ramp rate and response time tests into one section is that they are both described in this single figure.

The discharge test routine for response time and ramp rate has been revised, as follows, and the presentation of discharge-related requirements now precedes the presentation of charge-related requirements in the document:

- The manufacturer no longer specifies the SOC of the system at the start of the test. Now the ESS is required to be at 50% SOC.
- The specificity of when the data acquisition system (DAS) records a change in set point from rest is now more detailed to indicate this occurs when the discharge output command is sent to the ESS. In addition, the DAS is now also required to record the point in time at which the ESS actually responds to that command.
- The point in time at which the output of the ESS is considered to have discharged the system has been changed from within 2% of its rated power to be 100% +/- 2% of its rated power capacity.
- The discharge ramp rate is still required to be reported as a function of megawatts per minute but a new metric of expressing discharge ramp rate as a percentage of rated power per unit time has been added.

The charge test routine has been revised to mirror the discharge test routine as discussed above, the difference being the focus is now on charging rather than discharging the ESS. As with the discharge test, the SOC of the system is 50% at the beginning of the test.

Two new metrics have been added for frequency-regulation applications based on input from the users' subgroup. The SOC of the ESS during testing conducted pursuant to the protocol must be monitored and continuously updated by integrating the current with respect to time for each half-cycle (when the current or power is of the same sign) and adding the integrated value to the SOC at the beginning of this half-cycle. Energy capacity stability is also to be determined by dividing the stored energy capacity by the initial stored energy capacity determined immediately before and after initial application of the 72-hour duty cycle. The issue of energy storage stability was raised as being needed to address ESS degradation. This section establishes the basis for the initial energy capacity (e.g., new) and the methodology for addressing stability at any point in time in the future (e.g., rerunning the stored energy capacity test to determine energy capacity at any point in time after the ESS has been in operation).

Section 8.0

The provisions for reporting performance results have been revised to track with the revisions described above related to what testing is performed and how data measured are to be used and how the results for selected metrics are to be reported. For instance, stored energy capacity and RTE are based on a minimum of two cycles of data as opposed to eight. The duty-cycle RTE report has been changed to report the relevant test information for each duty cycle (A, B, and C) and in Section 8.1.2 to include reporting of the percentage of rated power achieved during discharge. In addition, at the suggestion of a protocol user, a requirement that the tabular data for duty-cycle roundtrip efficiency be provided in a graphical format has also been added.

New measurement methods have been added to provide for the determination and reporting of new metrics as discussed above. These are capacity stability and power factor for both applications, roundtrip efficiency as a function of discharge power for peak shaving, and SOC excursions for frequency-regulation applications.

Section 9.0

Two new references have been added for new standards referenced in the document. ANSI/ASHRAE Standard 105 is referenced as a basis for combining different energy forms into a single unit as discussed above regarding a basis for comparison of electrical and thermal systems. Institute of Electrical and Electronics Engineers Standard 1459 [1] is referenced as a basis for determining power factor.

Appendix A

Two errors, attributed to the transfer of the information in an Excel file to the published protocol, were found in the data presented in Appendix A. The errors (the signal for 57:36 to 59:16 being misplaced and the signal for 1:59:40 to 1:59:56 being omitted) have been corrected.

Appendix B

A new Appendix B that provides a reference to the details and data associated with the duty-cycle signal for ESSs supporting islanded microgrid applications has been added. Rather than unduly increase the length of the protocol, the report “Determination of the Duty Cycle for Energy Storage Systems Integrated with a Microgrid,” PNNL-23390, includes the data for the duty-cycle and additional documentation associated with the inclusion of islanded microgrid applications in the protocol.

Acronyms and Abbreviations

AC	alternating current
ANSI	American National Standards Institute
ASHRAE	American Society of Heating, Refrigerating and Air Conditioning Engineers
BMS	battery management system
Btu	British thermal unit
DAS	data acquisition system
ESS	energy storage system
°F	degree(s) Fahrenheit
IEEE	Institute of Electrical and Electronics Engineers
kW	kilowatt(s)
kWh	kilowatt-hour(s)
RTE	roundtrip energy efficiency
SOC	state-of-charge
min	minute(s)
MW	megawatt(s)
T_{max}	maximum temperature
T_{min}	minimum temperature
VAR	volt-ampere(s) reactive
Wh	watt-hour(s)

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Normative Appendix A − Duty-Cycle Signal for Frequency-Regulation Applications of Energy Storage Systems A.1
Normative Appendix B − Duty-Cycle Signal for Islanded Microgrid Applications of Energy Storage Systems B.1

Following are placeholders for future materials to facilitate an understanding and use of the protocol.

- Normative Appendix C − Establishing Energy Storage System Boundary Conditions
- Normative Appendix D − Form 1 – Data Reporting
- Normative Appendix E − Form 2 – Performance Summary
    - Storage Device Characteristics
    - Power Conversion System Characteristics
    - Monitors and Controls Characteristics
    - Full Energy Storage System Characteristics
- Informative Appendix F – Examples
- Informative Appendix G − Additional Description of Existing Standards

Protocol for Uniformly Measuring and Expressing the Performance of Energy Storage Systems

1.0 Purpose

This protocol provides a set of "best practices" for characterizing energy storage systems (ESSs) and measuring and reporting on their performance. It serves as a basis for assessing how an ESS will perform with respect to key performance attributes relevant to different applications. It is intended to provide a valid and accurate basis for the comparison of different ESSs. By achieving the stated purpose, the protocol will enable more informed decision-making in the selection of ESSs for various stationary applications.

2.0 Scope

The protocol defines a set of test, measurement, and evaluation criteria with which to express the performance of ESSs that are intended for energy-intensive and/or power-intensive stationary applications. An ESS includes a storage device, battery management system, and any power conversion systems installed with the storage device. The protocol is agnostic with respect to the storage technology and the size and rating of the ESS.

The protocol does not apply to single-use storage devices and storage devices that are not coupled with power conversion systems, nor does it address safety, security, or operations and maintenance of ESSs, or provide any pass/fail criteria.

3.0 Definitions

The following definitions shall be applied within the context of this protocol for the purposes of performance testing. To be useful, test procedures must include definitions to narrow the margin for interpretation and increase the repeatability of tests. Terms not defined shall have their normal dictionary meaning and be applied as such when using the protocol.

Area Control Error. A measure of the deviation of the actual interchange energy from the scheduled interchange energy on the ties with adjacent balancing authorities coupled with a frequency error component, a meter error component, a time error correction term, and an inadvertent energy payback term.

Area Regulation. A control signal from the balancing authority to devices that will respond to the control signal within the time frame specified by the balancing authority through a calculation by the balancing authority's energy management system of the area control error.

Balancing Authority. The responsible entity that integrates resource plans ahead of time, maintains load-interchange-generation balance within a balancing authority area, and supports interconnection frequency in real time.

Black Start. Black start refers to the process of restoring electric power from a complete blackout, without relying on an external power source.

Duration. The discharge time at rated power from the upper state-of-charge (SOC) limit to the lower SOC limit as specified for the application.

Duty Cycle. A charge/discharge profile that represents the demands associated with a specific application that is placed on an ESS.

Energy Efficiency. The useful energy output divided by the energy input to the ESS expressed as a percentage [1], including all parasitic energies needed to run the system, such as heating or cooling.

Energy Storage System Manufacturer. The entity that designs and assembles the various components that compose the ESS.

Frequency Regulation. Regulation of electric power frequency provided by generating units that are online and increase or decrease power as needed and provided by ESSs that provide "up" regulation by discharging and "down" regulation by charging. This is also considered as the use of generation, loads, and energy storage to control system frequency within a predetermined bandwidth and the inclusion of local devices, such as a generator governor a relay or a phasor management unit, that continuously measure frequency and then send a control signal to a device to increase or decrease the amount of energy injected into the grid or the amount of load on the grid.

Microgrid. A group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid and which can connect and disconnect from the grid to enable it to operate in either grid-connected or island mode and is not limited by size but by functionality.

Islanded Microgrid. An energy storage application that includes multiple loads and distributed energy generation and storage resources that is operated as an electrical island separate from the utility grid.

Peak-Shaving. An energy storage application that requires a duration of discharge of the ESS during the daily on-peak period for electric power (on the order of 2 to 12 hours) and is intended to recharge in the daily off-peak period for electric power and be available again the following day.

Power Factor. The ratio of the true power (alternating current [AC]), the capacity of the circuit for performing work in a particular time following the load, to the apparent power (AC) in the circuit expressed as a value between zero and one.

Power Performance, Electrical. The maximum electric power sustainable for a given duration of discharge.

Power Performance, Thermal. The maximum thermal power sustainable for a given duration of discharge.

Ramp Rate. The rate of change of power delivered to or absorbed by an ESS over time expressed in megawatts per minute or as a percentage change in rated power over time (percent per minute).

Rated Power. The power performance of the ESS for a particular application.

Reference Performance Test. A set of tests performed at the beginning of the life of an ESS to establish the baseline initial performance of the ESS and at periodic intervals thereafter to determine the performance degradation of the ESS during its operating life.

Roundtrip Energy Efficiency (RTE). The useful energy output from an ESS divided by the energy input into the ESS over one duty cycle under normal operating conditions, expressed as a percentage.

Response Time. The time in seconds it takes an ESS to reach 100 percent of rated power during charge or to discharge100 percent of rated power during discharge from an initial measurement taken when the ESS is at rest.

Stored Energy Capacity. The amount of electric or thermal energy capable of being stored by an ESS expressed as the product of rated power of the ESS and the discharge time at rated power.

4.0 Overview

4.1 Intent. The intent of this section is to provide an overview of the protocol and how it is intended to be used to determine the performance of an ESS. The first step in using the protocol is to identify the ESS and its intended application. These activities shall be performed in accordance with the provisions in Sections 4.2 and 4.3. Based on the intended application of the ESS, Section 4.4 shall be used in identifying the duty cycle to be applied and data to be collected at the ESS boundary as defined by the manufacturer of the ESS in accordance with the provisions in Section 4.2. Section 4.5 shall be used in defining the collected data that are to be used to determine the performance metrics applicable to the selected application(s). The reporting and presentation of the ESS performance based on the application and use of the collected data shall be in accordance with the provisions in Section 4.6. Figure 4.1 provides an overview of the approach embodied in the protocol and shows current ESS applications.

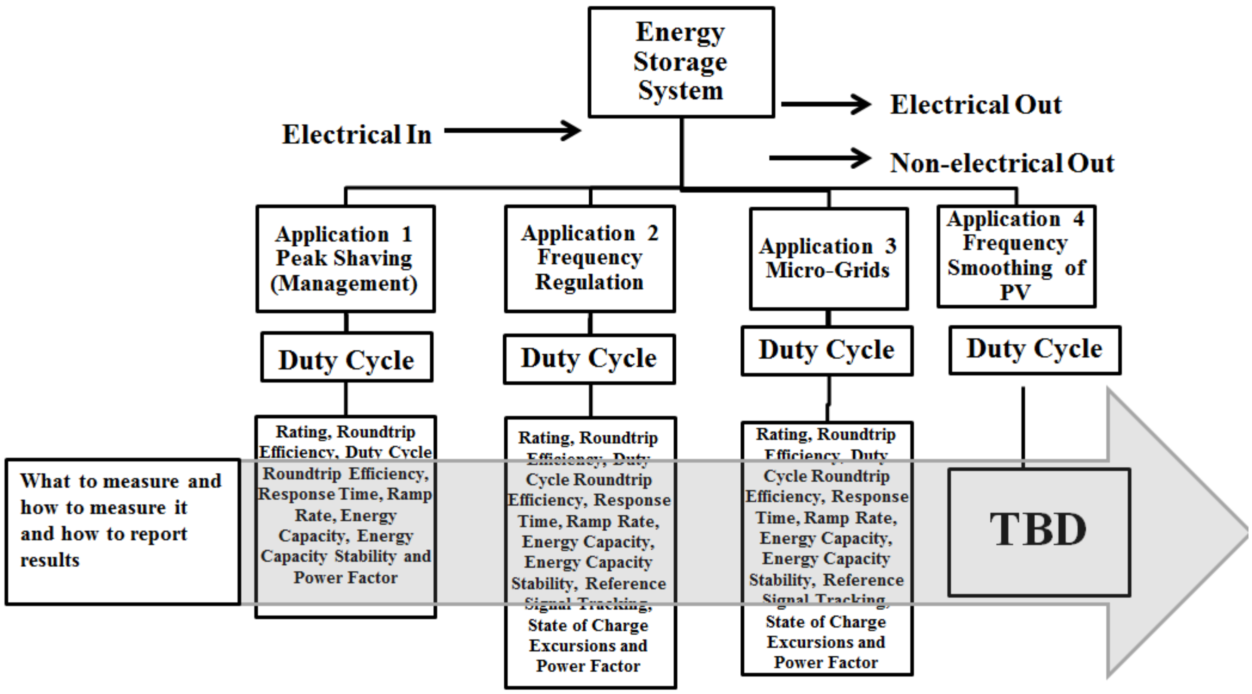

Figure 4.1. Protocol Overview

4.2 Description of the Energy Storage System. The ESS shall be described by the ESS manufacturer via an ESS inventory, which shall include the devices, components, controls, and other components associated with the ESS. This description shall also include at a minimum the weight, volume, and footprint of the ESS. The description shall identify the boundary within which the ESS, as described in Section 2.0, resides and the type and purpose of each input and output that crosses the ESS boundary. In describing the ESS, the manufacturer shall also provide information necessary to clearly define the communication interface across the ESS boundary. This shall include a description of the type, quality, and the source of and destination for all information sent from and received by the ESS. This information shall be available for application and use in designing the interfaces to be used for tests and data collection associated with the application of this protocol. Where the ESS is constructed from a number of separate components (non-unitary or prepackaged system) these responsibilities of the manufacturer shall apply to the entity that is designing the ESS and overseeing its installation and commissioning (designer/installer) based on information provided to them by the manufacturer(s) of the components making up the ESS. The assignment of responsibility throughout the protocol refers to the manufacturer; however, in the case of an ESS that is not unitary or a matched assembly of components, the manufacturer shall be considered the ESS designer/installer for the purpose of assigning responsibility.

4.3 Identification of the ESS Application. The intended application(s) of the ESS shall be identified in accordance with Table 4.3. Identification of the intended application for a prepackaged or unitary ESS or ESS assembled from matched components by one ESS manufacturer shall be conducted by the manufacturer of the ESS. Identification of the intended application for an ESS not having a singular manufacturer but instead is composed of an assembly of components to make up the ESS shall be conducted by the designer of the ESS.

Table 4.3. Energy Storage System Applications

Intended Application of the System
Peak Shaving (Management) (See Section 4.3.1)
Frequency Regulation (See Section 4.3.2)
Islanded Microgrids (See Section 4.3.3)

4.3.1 Peak Shaving (Management). Energy storage systems intended for peak-shaving applications shall be classified as all electric or electric/thermal systems. All ESSs, regardless of their classification, shall meet the provisions of this section.

Energy storage systems shall be identified by their application classification in accordance with the provisions in Section 5.1.1. All required testing, calculations, and/or simulations to determine the performance of any ESS intended for peak-shaving (management) applications shall be conducted in accordance with the duty cycle provided in Section 5.1.3.

4.3.1.1 System Rating. The rating of the ESS shall be determined in accordance with the provisions in Section 5.1.2.

4.3.1.2 Roundtrip Energy Efficiency. The RTE of the ESS shall be determined in accordance with the provisions in Section 5.1.4.1.

4.3.1.3 Duty-Cycle Roundtrip Efficiency. The duty-cycle roundtrip efficiency of the ESS shall be determined in accordance with the provisions in Section 5.1.4.2.

4.3.1.4 Response Time. The response time of the ESS shall be determined in accordance with the provisions in Section 5.1.4.3.

4.3.1.5 Ramp Rate. The ramp rate of the ESS shall be determined in accordance with the provisions in Section 5.1.4.3.

4.3.1.6 Energy Capacity. The energy capacity of the ESS shall be determined in accordance with the provisions in Section 5.1.4.4.

4.3.1.7 Energy Capacity Stability. The energy capacity stability of the ESS shall be determined in accordance with the provisions in Section 5.1.4.5.

4.3.1.8 Power Factor. The power factor of any inverter serving as a component of the ESS shall be determined in accordance with the provisions in Section 5.1.4.6.

4.3.2 Frequency Regulation. Energy storage systems that are intended to be applied for frequency regulation shall have their performance determined in accordance with the provisions in Section 5.2. All required testing, calculations and/or simulations to determine the performance of any ESS intended for frequency regulation shall be conducted in accordance with the duty cycle provided in Section 5.2.2.

4.3.2.1 System Rating. The rating of the ESS shall be determined in accordance with the provisions in Section 5.2.1.

4.3.2.2 Roundtrip Energy Efficiency. The RTE of the ESS shall be determined in accordance with the provisions in Section 5.2.3.1.

4.3.2.3 Duty-Cycle Roundtrip Efficiency. The duty-cycle roundtrip efficiency of the ESS shall be determined in accordance with the provisions in Section 5.2.3.2

4.3.2.4 Response Time. The response time of the ESS shall be determined in accordance with the provisions in Section 5.2.3.3.

4.3.2.5 Ramp Rate. The ramp rate of the ESS shall be determined in accordance with the provisions in Section 5.2.3.3.

4.3.2.6 Energy Capacity. The energy capacity of the ESS shall be determined in accordance with the provisions in Section 5.2.3.4.

4.3.2.7 Energy Capacity Stability. The energy capacity stability of the ESS shall be determined in accordance with the provisions in Section 5.2.3.5.

4.3.2.8 Reference Signal Tracking. The ability of the ESS to respond to a reference signal shall be determined in accordance with the provisions in Section 5.2.3.6.

4.3.2.9 State-of-Charge Excursions. The maximum and minimum excursions of the state of charge (SOC) of the ESS shall be determined in accordance with the provisions of Section 5.2.3.7.

4.3.2.10 Power Factor. The power factor of any inverter serving as a component of the ESS shall be determined in accordance with the provisions in Section 5.2.3.8.

4.3.3 Islanded Microgrids. Energy storage systems that are intended to be applied in an islanded microgrid shall have their performance determined in accordance with the provisions in Section 5.3. All required testing, calculations and/or simulations to determine the performance of any ESS intended for an islanded microgrid shall be conducted in accordance with the duty cycle provided in Section 5.3.2.

4.3.3.1 System Rating. The rating of the ESS shall be determined in accordance with the provisions in Section 5.3.1.

4.3.3.2 Roundtrip Energy Efficiency. The RTE of the ESS shall be determined in accordance with the provisions in Section 5.3.3.1.

4.3.3.3 Duty-Cycle Roundtrip Efficiency. The duty-cycle roundtrip efficiency of the ESS shall be determined in accordance with the provisions in Section 5.3.3.2

4.3.3.4 Response Time. The response time of the ESS shall be determined in accordance with the provisions in Section 5.3.3.3.

4.3.3.5 Ramp Rate. The ramp rate of the ESS shall be determined in accordance with the provisions in Section 5.3.3.3.

4.3.3.6 Energy Capacity. The energy capacity of the ESS shall be determined in accordance with the provisions in Section 5.3.3.4.

4.3.3.7 Energy Capacity Stability. The energy capacity stability of the ESS shall be determined in accordance with the provisions in Section 5.3.3.5.

4.3.3.8 Reference Signal Tracking. The ability of the ESS to respond to a reference signal shall be determined in accordance with the provisions in Section 5.3.3.6.

4.3.3.9 State-of-Charge Excursions. The maximum and minimum excursions of the SOC of the ESS shall be determined in accordance with the provisions of Section 5.3.3.7.

4.3.3.10 Power Factor. The power factor of any inverter serving as a component of the ESS shall be determined in accordance with the provisions in Section 5.3.3.8.

4.4 Measurement Procedure. Measurements shall be conducted in accordance with the test conditions, data acquisition conditions, and test procedures in Section 7.0, the use of which is intended to produce the accurate and repeatable data necessary to calculate the performance metrics relevant to the application.

4.4.1 Input. The data associated with input(s) to the ESS across the designated system boundary shall be determined in accordance with the provisions in Section 6.2.

4.4.2 Output. The data associated with outputs(s) from the ESS across the designated system boundary shall be determined in accordance with the provisions in Section 6.3.

4.5 Determining Relevant Performance Metrics. The performance of the ESS shall be determined using the data collected pursuant to Section 5.0 and applied in accordance with the provisions in Section 7.0. The intended application of the ESS shall be used to define what metrics are to be used and the measurement procedure and collected data shall be used to provide the information necessary to derive the values for these metrics for the ESS being evaluated. In determining system performance, the energy use associated with determining a particular metric shall be converted to a single consistent and comparable metric. All required conversions necessary to derive the reported value of the metric shall be in accordance with American National Standards Institute/American Society of Heating, Refrigerating and Air Conditioning Engineers (ANSI/ASHRAE) Standard 105.

4.6 Reporting and Displaying Performance. The performance of the ESS for each intended application shall be reported in accordance with the provisions in Section 8.0 and included in a permanent label affixed to the system or included with the ESS specifications. Where the system has multiple applications, the determination and reporting of performance shall be conducted separately for each application.

The reporting of ESS performance in accordance with the provisions in Section 8.0 shall not preclude the reporting of other information associated with the ESS. Such information shall include but not be limited to the battery cell or module voltage and temperature, the expected service and cycle life of the ESS or any of its components, specific energy and energy density of battery cells or modules, and power or energy capacity degradation over time as deemed appropriate and necessary by the ESS manufacturer. Where such additional information is to be provided by the ESS manufacturer, it shall be reported on the required ESS label or included with the ESS specifications and accompanied by a reference to the standard, measurement method, or other basis for determining the information reported and the duration of and increments in time at which the measurements were taken and the error margin associated with those measurements.

5.0 Applications

5.1 Peak Shaving (management). Energy storage systems intended for use in peak-shaving (management) applications shall have their performance determined in accordance with this section.

5.1.1 Classification. Energy storage systems intended for peak-shaving (management) applications shall be designated by their intended classification(s) as described in Sections 5.1.1.1 through 5.1.1.11.

5.1.1.1 Energy Time Shift (Arbitrage). Energy time shift (arbitrage) shall be considered a use classification of an ESS in a peak-shaving (management) application where the system is charged during low energy price periods and discharged during high energy price periods where either the ESS owner pays wholesale market energy rates plus a delivery charge or pays time of day retail rates.

5.1.1.2 Electric Supply Capacity. Electric supply capacity shall be considered a use classification of an ESS in a peak-shaving (management) application where the storage capacity of the system is used to defer the installation of new electric generation capacity, such as, but not limited to, a relatively small storage system or series of systems where growth has created a need for generation that cannot be satisfied in the short term and the storage system would be expected to supply load over the full period when the excess capacity is needed.

5.1.1.3 Load Following. Load following shall be considered a use classification of an ESS in a peak-shaving (management) application where the system is used to reduce ramp rate magnitudes so that conventional load-following generating units can better moderate cycling and be brought on at, or near, full load.

5.1.1.4 Transmission Congestion Relief. Transmission congestion relief shall be considered a use classification of an ESS in a peak-shaving (management) application that is a special case of the energy time shift use classification in Section 5.1.1.1, where electric transmission congestion leads to price differences across a transmission system at the same point in time. In this use classification, the storage system shall be located on the load side of the congested network, charged in low price periods when the system is not congested and discharged during high price time periods when prices have increased due to congestion.

5.1.1.5 Distribution System Upgrades Deferral. Distribution system upgrade deferral shall be considered a use classification of an ESS in a peak-shaving (management) application where the system responds to a situation where a piece of equipment on the distribution system, including power line conductors, experiences loadings that approach the distribution system equipment's rated capacity, thereby allowing the current distribution system equipment to remain online longer until other conditions necessitate that the distribution system equipment be upgraded.

5.1.1.6 Transmission System Upgrades Deferral. Transmission system upgrade deferral shall be considered a use classification of an ESS in a peak-shaving (management) application identical to the distribution upgrade deferral application covered in Section 5.1.1.5, except that it applies on higher voltages and higher power conditions found on the electric transmission system.

5.1.1.7 Retail Demand Charge Management. Retail demand charge management shall be considered a use classification of an ESS in a peak-shaving (management) application where the system is applied and used to minimize the demand charge from a utility over the course of each month.

5.1.1.8 Wind Energy Time Shift (Arbitrage). Wind energy time shift shall be considered a use classification of an ESS in a peak-shaving (management) application where electric power generated from a wind technology during low price periods is stored and then delivered during high wholesale price periods.

5.1.1.9 Photovoltaic Energy Time Shift (Arbitrage). Photovoltaic energy time shift shall be considered a use classification of an ESS in a peak-shaving (management) application where electric power generated from photovoltaic technology is stored and then delivered to the system when needed.

5.1.1.10 Renewable Capacity Firming. Renewable capacity firming shall be considered a use classification of an ESS in a peak-shaving (management) application that involves the coupling of intermittent renewable generation with a specific capacity and type of energy storage that allows for an increase in the ability of the renewable generation to participate in the capacity market.

5.1.1.11 Baseload Generation Time Shift. Baseload generation time shift shall be considered a use classification of an ESS in a peak-shaving (management) application where an ESS is configured to allow baseload units to operate at full capacity during lighter nighttime loads, and deliver energy to the system in a way that minimizes or displaces higher-cost peaking generation.

5.1.2 System Ratings. Ratings for ESSs covering rated power and energy available at rated power and the performance of the ESS associated with response time, ramp rate, and RTE at the beginning of life shall be based on a set of ambient operating conditions specified by the manufacturer of the ESS. The manufacturer shall also provide an indication of how the performance of the ESS is expected to change over time to account for time and use of the system.

The determination and reporting of ratings for ESSs applied in a peak-shaving (management) application shall be in accordance with Institute of Electrical and Electronics Engineers (IEEE) Standard 1679 as expanded herein to provide more specific test procedures that apply to peak-shaving (management) applications. Such expansion shall include application of the duty cycle in Section 5.1.3 and taking measurements needed to determine the values for the metrics in Section 5.1.4 in determining and expressing the performance of ESSs for peak-shaving (management) applications.

5.1.3. Duty Cycle. The duty cycles presented in this section shall be used in the determination of the performance of systems intended for peak-shaving (management) applications and shall use charge and discharge time windows instead of normalized power levels or discharge rates to allow the duty-cycle profile to be applied the same to different technologies regardless of system size, type, age, and condition. The duty cycles applied in determining system performance shall be in accordance with Figure 5.1.3 and the provisions in Sections 5.1.3.1 through 5.1.3.4.

Each cycle must have a total charge time of 12 hours, a variable duration discharge window and two equal float windows that bring the total duration for each of the A, B, and C profiles to one 24-hour period. While Figure 5.1.3 displays these profiles for a midnight-to-midnight day with an evening peak, for the purposes of testing any start and end time shall be permitted to be selected as long as that time period is for 24 continuous hours. When conducting performance tests using these profiles, the baseline point selected from which to start the test and representing the beginning of each duty cycle shall be the same point the system is returned to after the 24-hour duration of the test profile. This baseline point shall be at any SOC of the ESS.

5.1.3.1 Charge Window. During the charge window, the ESS shall be charged at constant power in a 12-hour time period to bring the ESS to its upper SOC limit, after which the ESS shall be maintained at that SOC limit in accordance with the ESS manufacturer's specifications and operating instructions.

5.1.3.2 Float Window. During the float window the operation of any internal support loads for the ESS such as, but not limited to, heating, ventilation, and air-conditioning systems shall continue to operate as required in accordance with the ESS manufacturer's specifications and operating instructions. During the float window the ESS shall not be maintained at the top of charge from an external source. Discharging of the ESS that does not serve a load external to the ESS shall be permitted during the float window.

5.1.3.3 Discharge Window. During the discharge window the ESS shall be discharged until the minimum SOC level, as specified by the ESS manufacturer, is reached. The discharge of the ESS shall be at constant power as specified by the manufacturer of the ESS to bring the ESS to its minimum SOC level as specified by the manufacturer for a peak-shaving application.

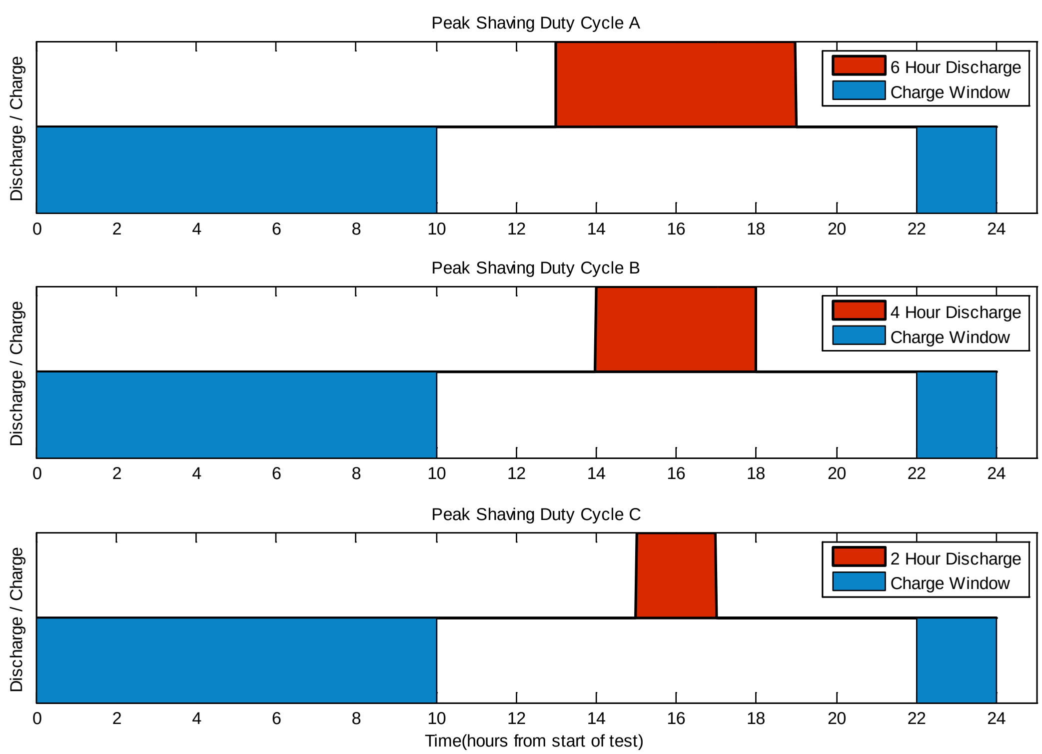

Figure 5.1.3. Peak-Shaving Duty Cycles

5.1.3.4 Application of the Duty Cycles. Performance testing, shall be run over a 72-hour period and consist of one application of duty-cycle A and bringing the ESS back to its initial state of charge, followed immediately by one application of duty-cycle B and then followed immediately by one application of duty-cycle C as shown in Figure 5.1.3, with the ESS brought back to its initial SOC after each duty cycle. These duty cycles, sequenced as required above, shall be used to calculate the metrics covered in Section 5.1.4 that are to be used as a basis for determining and reporting the operational effectiveness of an ESS in peak-shaving applications.

5.1.4 Performance Metrics. The performance of the ESS shall be expressed in accordance with the provisions of Sections 5.1.4.1 through 5.1.4.6 based on the application of the duty cycle provided in Section 5.1.3.

5.1.4.1 Roundtrip Energy Efficiency. The RTE of the ESS shall be determined in accordance with the provisions in Section 7.4.1.

5.1.4.2 Duty-Cycle Roundtrip Efficiency. The duty-cycle roundtrip efficiency of the ESS as a function of discharge power shall be determined in accordance with the provisions in Section 7.4.2.

5.1.4.3 Response Time and Ramp Rate. The response time associated with an ESS does not regulate power or frequency but does respond to energy prices that will vary over the course of several minutes or hours. This includes peak-shaving applications that require the ESS to respond to and capitalize on sudden peaks in energy generation from renewable or waste energy resources or energy prices when improved use of the stored energy in a very short period of time (e.g., minutes) is to be assessed. Where the response time of an ESS is to be reported, it shall be determined in accordance with the provisions in Section 7.5. The ramp rate of the ESS is the ratio of ESS rated power to the response time and shall be determined in accordance with the provisions in Section 7.5.

5.1.4.4 Energy Capacity. The energy capacity of ESS shall be determined in accordance with the provisions in Section 7.3.

5.1.4.5 Energy Capacity Stability. The energy capacity stability of the ESS shall be determined in accordance with the provisions in Section 7.7.

5.1.4.6 Power Factor. The power factor of any inverter supplied as a component of the ESS shall be determined in accordance with IEEE Standard 1459 and reported as required in Section 8.1.5.

5.2 Frequency Regulation. Energy storage systems intended for use in frequency regulation shall have their performance determined in accordance with this section. Frequency regulation shall be permitted to represent area regulation as used by a balancing authority to meet North American Electric Reliability Corporation Balancing Authority Performance Control Standards.

5.2.1 System Ratings. Ratings for ESSs covering rated power and energy available at rated power and the performance of the ESS covering response time, ramp rate, and RTE at the beginning of life shall be based on a set of ambient conditions specified by the manufacturer of the ESS. The manufacturer shall also provide an indication of how the performance of the ESS is expected to change over time to account for time and use of the ESS.

The determination and reporting of ratings for an ESS to be applied for frequency regulation shall be in accordance with the provisions of this section using the duty cycle in Section 5.2.2 and metrics in Section 5.2.3.

5.2.2 Duty Cycle. The duty cycle to be applied in determining the performance of an ESS for a frequency-regulation application is shown in Figure 5.2.2 as power normalized with respect to the rated power of the ESS over a 24-hour time period, where positive represents charge into the ESS and negative represents discharge from the ESS as a function of time in hours. The raw data upon which Figure 5.2.2 is based are included in Appendix A.

The ESS manufacturer shall be permitted to conduct additional testing using another duty cycle. Where this is done the manufacturer shall provide a description of and rationale for the duty cycle chosen, shall conduct all tests required herein while subjecting the ESS to the additional duty cycle chosen and report all performance measures as required in Section 8.0 under the designation "alternative duty-cycle [insert source or name]."

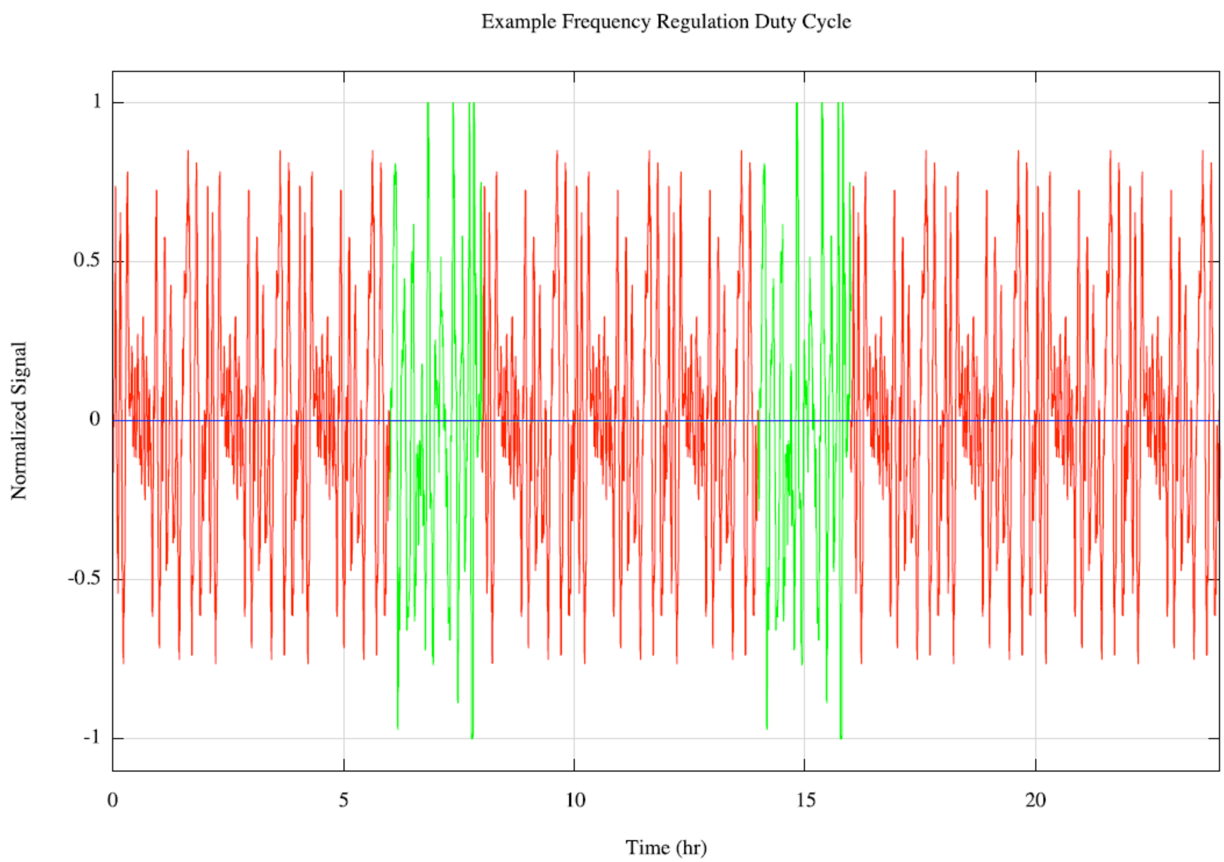

Figure 5.2.2. Frequency-Regulation Duty Cycle

5.2.3 Performance Metrics. The performance of the ESS shall be expressed in accordance with the provisions of Sections 5.2.3.1 through 5.2.3.9 based on the application of the duty-cycle regimen provided in Section 5.2.2.

5.2.3.1 Roundtrip Energy Efficiency. The RTE of the ESS shall be determined in accordance with the provisions in Section 7.4.1.

5.2.3.2 Duty-Cycle Roundtrip Efficiency. The duty-cycle roundtrip efficiency of the ESS shall be determined in accordance with the provisions in Section 7.4.3.

5.2.3.3 Response Time and Ramp Rate. The response time of the ESS shall be measured in accordance with Section 7.5 as the time for the system to reach 100% (±2%) of the rated power level from rest during charge or discharge after receiving the balancing signal with the ESS at a 50% SOC. The ramp rate of the ESS shall be determined by dividing the ESS rated power by the response time in accordance with the provisions in Section 7.5.

5.2.3.4 Energy Capacity. The energy capacity of the ESS shall be determined in accordance with the provisions in Section 7.3.

5.2.3.5 Energy Capacity Stability. The energy capacity stability of the ESS shall be determined in accordance with the provisions in Section 7.7.

5.2.3.6 Reference Signal Tracking. The ability of the ESS to respond to signal for the 24-hour duty cycle and that reflects the ability of the ESS to track the signal shall be defined and determined by the manufacturer of the ESS in accordance with the provisions in Section 7.4.5. The balancing signal shall be changed every 4 seconds during the duty cycle.

In addition, the manufacturer of the ESS shall also determine and report separately the total percentage tracking and the times when the ESS stops tracking and restarts tracking as an indication of whether the ESS is capable of tracking high peaks and/or high energy half cycles. The manufacturer shall also determine if the ESS can go through a 24-hour period without reaching the lower or upper SOC limits. This shall be performed during the 24-hour duty cycle as described in Section 5.2.2, and any time during that period when the ESS indicates ability or inability to follow the signal shall be reported. An inability to follow the signal shall be considered a situation where the ESS cannot deliver or absorb required signal power during the 4-second duration and cannot deliver or absorb the required signal energy during the duration when the signal remains above or below the x-axis. The total time the ESS cannot follow the signal and percentage tracked shall be determined in accordance with the provisions in Section 7.4.5.

5.2.3.7 State-of-Charge Excursions. The maximum and minimum excursions of the SOC of the ESS during the duty cycle provided in Section 5.2.2 shall be determined in accordance with the provisions in Section 7.6. During the conduct of the tests provided in Section 5.2.3 the ESS SOC shall not cross the thresholds provided in the manufacturer's specifications and operating conditions.

5.2.3.8 Power Factor. The power factor of any inverter supplied as a component of the ESS shall be determined in accordance with IEEE Standard 1459 and reported as required in Section 8.2.7.

5.3 Islanded Microgrids. Energy storage systems intended for use in an islanded microgrid application shall have their performance determined in accordance with this section.

5.3.1 System Ratings. Ratings for ESSs covering rated power and energy available at rated power and the performance of the ESS covering response time, ramp rate and RTE at the beginning of life shall be based on a set of ambient conditions specified by the manufacturer of the ESS. The manufacturer shall also provide an indication of how the performance of the ESS is expected to change over time to account for time and use of the ESS.

The determination and reporting of ratings for an ESS to be applied in an islanded microgrid application shall be in accordance with this section using the duty cycle in Section 5.3.2 and the metrics in Section 5.3.3.

5.3.2 Duty Cycle. The duty cycles to be applied in determining the performance of an ESS in an islanded microgrid application are shown in Figures 5.3.2 a, b and c as power normalized with respect to the rated power of the ESS over a 24-hour time period, where a positive sign represents charge into the ESS and a negative sign represents discharge from the ESS as a function of time in hours. A reference to the data upon which Figures 5.3.2 a, b and c are based is included in Appendix B.

The ESS manufacturer shall be permitted to conduct additional testing using another duty cycle. Where this is done, the manufacturer shall provide a description of and rationale for the duty cycle chosen, shall conduct all tests required herein while subjecting the ESS to the additional duty cycle chosen and report all performance measures as required in Section 8.0 under the designation "Alternative Duty Cycle [insert source or name]."

The first duty cycle in Figure 5.3.2a corresponds to the use of ESS in islanded microgrids including renewables and frequency regulation. The second duty cycle in Figure 5.3.2b corresponds to the use of ESS in islanded microgrids with renewables, and without frequency regulation. The third duty cycle in Figure 5.3.2c corresponds to the use of ESS in islanded microgrids without renewables and frequency regulation.

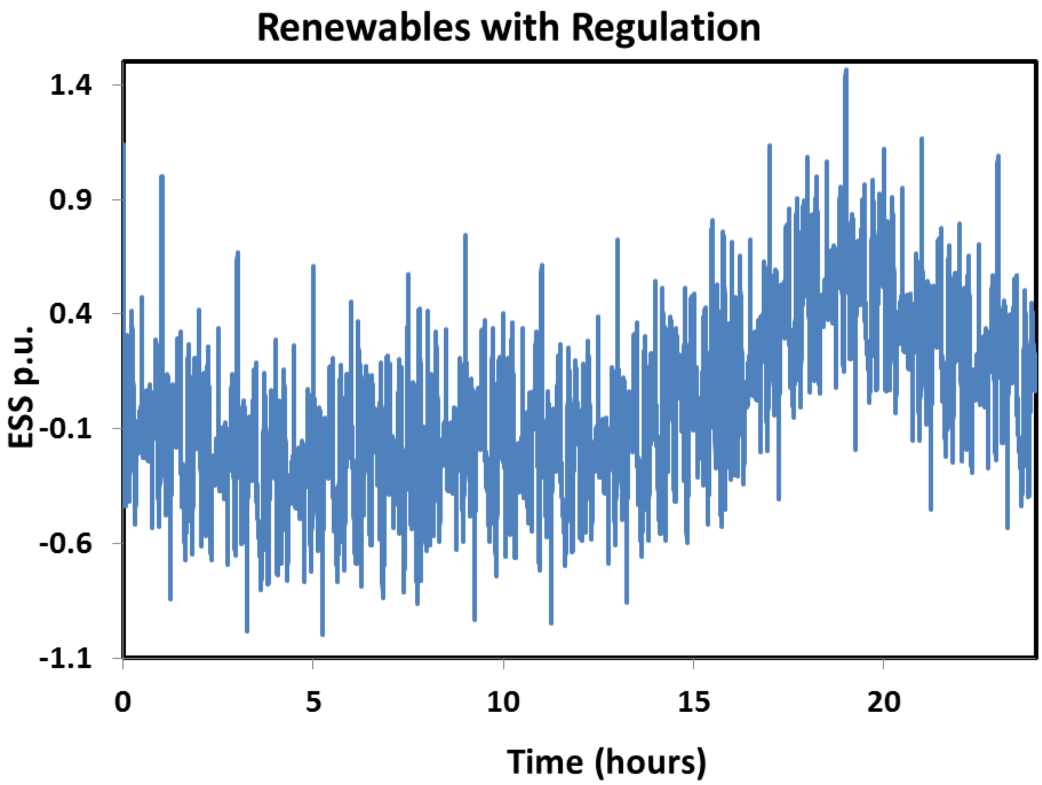

Figure 5.3.2a. Duty Cycle – Renewables with Frequency Regulation

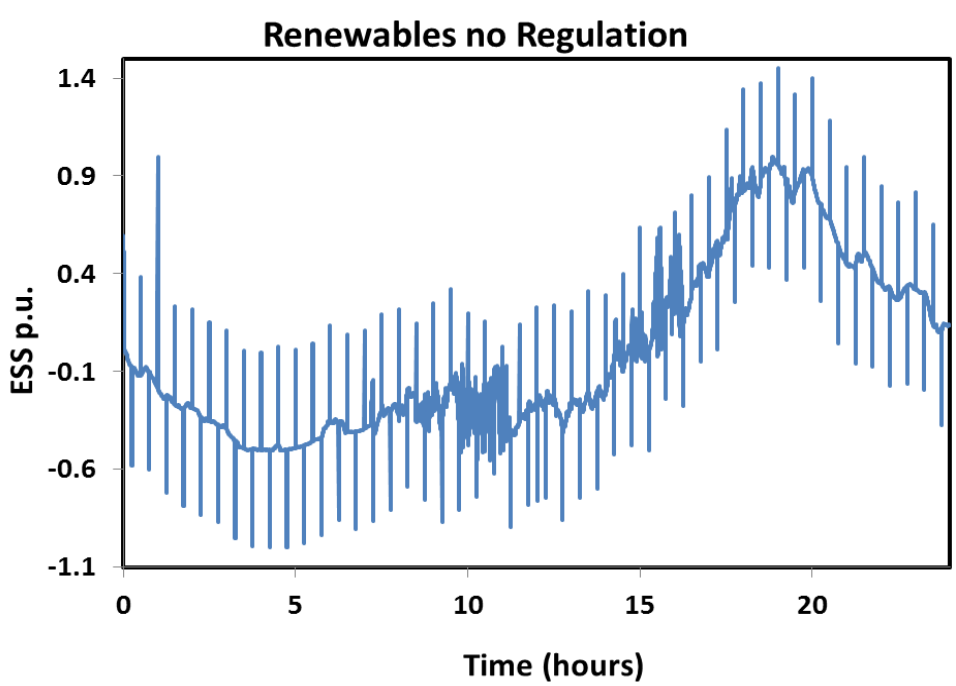

Figure 5.3.2b. Duty Cycle – Renewables with No Frequency Regulation

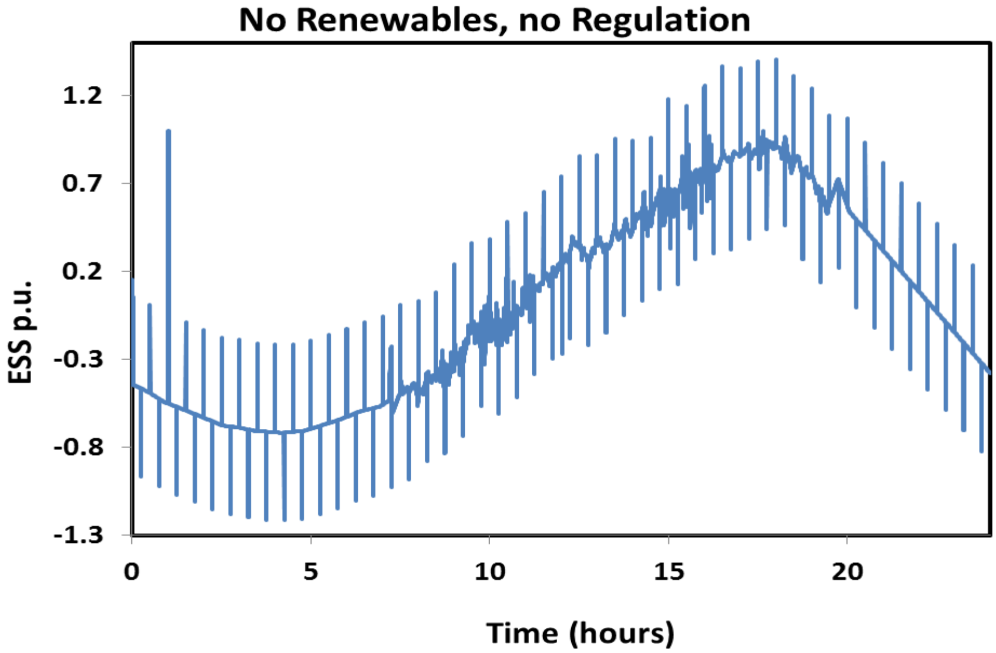

Figure 5.3.2c. Duty Cycle – No Renewables or Frequency Regulation

5.3.3 Performance Metrics. The performance of the ESS shall be expressed in accordance with the provisions of Sections 5.3.3.1 through 5.3.3.8 based on the application of the duty-cycle regimen provided in Section 5.3.2.

5.3.3.1 Roundtrip Energy Efficiency. The RTE of the ESS shall be determined in accordance with the provisions in Section 7.4.1

5.3.3.2 Duty-Cycle Roundtrip Efficiency. The duty-cycle roundtrip efficiency of the ESS shall be determined in accordance with the provisions in Section 7.4.4.

5.3.3.3 Response Time and Ramp Rate. The response time of the ESS shall be measured in accordance with Section 7.5 as the time for the system to reach 100% (±2%) of the rated power level from a condition when the ESS is neither charging or discharging (is at rest) during charge or discharge after receiving the balancing signal with the ESS at a 50% state of charge. The ramp rate of the ESS shall be determined by dividing the ESS rated power by the response time in accordance with the provisions in Section 7.5.

5.3.3.4 Energy Capacity. The energy capacity of the ESS shall be determined in accordance with the provisions in Section 7.3.

5.2.3.5 Energy Capacity Stability. The energy capacity stability of the ESS shall be determined in accordance with the provisions in Section 7.7.

5.3.3.6 Reference Signal Tracking for Duty Cycle A. The ability of the ESS to respond to the signal and that is reflective of the ability of the ESS to track the signal shall be defined and determined by the manufacturer of the ESS in accordance with the provisions in Section 7.4.5.

In addition, the manufacturer of the ESS shall also determine and report separately the total percentage the signal is tracked as well as the times when the ESS stops tracking and restarts tracking as an indication of whether the ESS is capable of tracking high peaks and/or high energy half cycles. Any time during which the ESS indicates ability or inability to follow the signal shall be reported. An inability to follow the signal shall be considered a situation in which the ESS cannot deliver or absorb required signal power during the duty cycle and cannot deliver or absorb the required signal energy during the interval when the signal remains above or below the x-axis. The total time the ESS cannot follow the signal and the percentage tracked shall be determined in accordance with the provisions in Section 7.4.5.

5.3.3.7 State-of-Charge Excursions. The maximum and minimum excursions of the SOC of the ESS during the duty cycles provided in Section 5.3.2 shall be determined in accordance with the provisions in Section 7.6. During the conduct of the tests provided in accordance with the duty cycles in Section 5.3.3, the ESS SOC shall not cross the thresholds provided in the manufacturer's specifications and operating conditions.

5.3.3.8 Power Factor. The power factor of any inverter supplied as a component of the ESS shall be determined in accordance with IEEE Standard 1459 and reported as required in Section 8.2.7.

6.0 Energy Storage Systems

6.1 Subsystems and Components. The manufacturer shall identify all subsystems and major components that compose the ESS on a schedule of ESS components that lists each subsystem or major component by name and model number. The schedule shall also list the input and output of each component in accordance with the provisions in Sections 6.2 and 6.3. Where the ESS is constructed from a number of separate components (non-unitary or prepackaged system), these responsibilities of the manufacturer shall apply to the entity that is designing the system and overseeing its installation and commissioning (designer/installer) based on information provided to it by the manufacturer(s) of the components making up the ESS.

6.2 Input Characteristics. The input of each subsystem and major component in terms of electrical power and/or thermal or non-electrical energy shall be determined in accordance with recognized standards and those standards used reported in conjunction with the data reported in Section 8.0.

6.3 Output Characteristics. The output of each subsystem and major component in terms of electrical power and/or thermal energy shall be determined in accordance with recognized standards and those standards used reported in conjunction with the data reported in Section 8.0.

7.0 Test Methods and Procedures

7.1 Comprehensive Data Recording. All measurements of charge rate, input current and voltage, output current and voltage, thermal output, system temperatures, ambient conditions, and other parameters that must be measured shall be collected simultaneously at a temporal resolution applicable to the function of the ESS application and ESS metrics to which they are being applied and in accordance with recognized standards applicable to the measurements being taken. All parameters measured and recorded shall be reported by the manufacturer in the ESS information model that must be used for further analysis and determination and reporting of ESS performance. All tests shall be conducted on the entire ESS as defined by the manufacturer or designer/installer of the ESS in accordance with the provisions in Section 4.2.

7.2 Reference Performance Test. A reference performance test shall be conducted in accordance with this section, and the results shall be used to determine baseline ESS performance that can be subsequently used as a baseline to assess any changes in the condition of the ESS and rate of performance over time and use. This test shall be repeated at regular intervals specified by the manufacturer during cycle testing for same-system comparison purposes. Such intervals shall be selected to identify how the testing or operation affects the performance of the ESS and shall be in units of time, number of cycles, or energy throughput. Unless specified otherwise, reference performance testing shall include the tests listed in Table 7.2.

Table 7.2. Reference Performance Tests

Peak Shaving (Management)	Frequency Regulation and Islanded Microgrids
Stored energy capacity test (Section 7.3)	Stored energy capacity test (Section 7.3)
Roundtrip energy efficiency test (Section 7.4.1)	Roundtrip energy efficiency test (Section 7.4.1
Response time and ramp rate test (Section 7.5)	Response time and ramp rate test (Section 7.5)
Duty-cycle roundtrip efficiency (Section 7.4.2)	Duty-cycle roundtrip efficiency for frequency-regulation applications (Section 7.4.3)
Energy capacity stability (Section 7.7)	Duty-cycle roundtrip efficiency for islanded microgrid applications (Section 7.4.4)
	Reference signal tracking test (Section 7.4.5)
	State-of-charge excursions (Section 7.6)
	Energy capacity stability (Section 7.7)

7.3 Stored Energy Capacity Test. A stored energy capacity test shall be performed in accordance with this section and is intended to be used to determine the stored energy capacity at the rated electrical or thermal power for the intended application as specified by the manufacturer.

7.3.1 Test Overview. The ESS shall be discharged to the lower SOC limit specified by the manufacturer. In conducting the stored energy capacity test, the manufacturer shall describe a detailed and documented charging procedure within the specifications of the ESS for charging the ESS in less than 12 hours to the upper SOC limit of the ESS. In addition, the manufacturer shall select a discharge time period at constant power output based on the intended application of the ESS. For an ESS intended for a peak-shaving (management) application, the discharge time period shall be selected between 2 and 12 hours or as recommended by the ESS manufacturer. For an ESS intended for a frequency regulation application, the minimum discharge time period shall be selected between 15 minutes and 1 hour or as recommended by the ESS manufacturer. For an ESS intended for an islanded microgrid application, the discharge time period shall be selected between 2 and 6 hours. Once this discharge time period is selected, all stored energy capacity tests conducted on the same ESS shall remain consistent and allow for properly tracking performance degradation.

Energy storage system power during charge and discharge shall be recorded at regular intervals of time or at step or percentage variances at a rate that is documented by the manufacturer to provide a statistically valid resolution. The associated energy input and output of the ESS shall be calculated from the recorded power.

7.3.2 Stored Energy Capacity Test Routine. The ESS shall be tested for its stored energy capacity at selected power in accordance with the procedure listed below. The measurements shall be collected in accordance with Section 7.3.1 throughout all test steps, listed below.

1. The ESS shall be discharged to its lower SOC limit in accordance with the system manufacturer's specifications and operating instructions and held at that SOC for at least 10 but not more than 30 minutes. That lower SOC shall be measured and recorded as the manufacturer-specified V_{min} (electrical storage), T_{min} (thermal storage without phase change), or P_{min} (thermal storage with phase change, where P is percentage mass of the solid phase for a solid-liquid phase change, and percentage mass of liquid phase for a liquid to gas phase change), corresponding to that lower SOC, under the manufacturer-specified discharge conditions.
2. The ESS shall be charged to its upper SOC limit in accordance with the system manufacturer's specifications and operating instructions and held at that SOC for at least 10 but not more than 30 minutes. That upper SOC shall be measured and recorded as V_{max} (electrical storage), T_{max} (thermal storage without phase change), or P_{max} (thermal storage with phase change, where P is percentage mass of the solid phase for a solid-liquid phase change, and percentage mass of liquid phase for a liquid to gas phase change), corresponding to the upper SOC, under the manufacturer-specified charge conditions. The energy input Wh_{Ii}, into the ESS during ESS charging, including all parasitic losses, shall be measured directly during charging and recorded as the charge energy capacity of the ESS.
3. Where the ESS manufacturer requires a rest time after charging and prior to discharging, the system shall be left at rest in an active state in accordance with the ESS manufacturer's operating instructions for at least 10 but not more than 30 minutes.
4. The system shall be discharged in accordance with the system manufacturer's specifications and operating instructions to the lower SOC limit at the discharge time prescribed by the duty cycle. That lower SOC shall be measured and recorded as V_{min} (voltage), T_{min} (thermal storage without phase change) or P_{min} (thermal storage with phase change), corresponding to the lower SOC limit associated with the manufacturer-specified discharge conditions. The energy output, $Wh_{Di,}$ from the ESS during ESS discharging shall be calculated from the power measurements during discharge and recorded.
5. The ESS shall be left at rest in an active standby state for the same period of time selected under Step 3 above.
6. Steps 2 through 5 above shall be repeated at least twice. The reference performance test value shall be calculated as the mean of the values of Wh_{Ii} and W_{Di} as measured under Steps 2 and 4 above associated with each test and the standard deviation also shall be calculated and reported.
7. The ESS shall be recharged in accordance with Step 2 and the ESS left in a fully charged state. The energy input for this step will not be used for calculation of RTE.

7.4 Roundtrip Energy Efficiency Test. A RTE test shall be conducted to determine the amount of energy that an ESS can deliver relative to the amount of energy injected into the ESS during the preceding charge. This test shall be performed as part of the reference performance test outlined in Section 7.2.

This test shall be performed using the energy test routine and the applicable duty cycle for the intended application of the system. The ESS shall be tested for its RTE in accordance with the test presented in Section 7.3.2.

7.4.1 Roundtrip Energy Efficiency from Stored Energy Capacity Test Routine. The RTE of the ESS is the efficiency for X-1 cycles and shall be determined in accordance with Equation 7-1 based on the data secured from the tests conducted in accordance with the provisions in Section 7.3.2. Where constant power cannot be held during the test the use of average power shall be considered acceptable and this noted when reporting RTE in accordance with the provisions in Section 8.1.1.

$$Round\ trip\ efficiency = \left(\left(\frac{\sum_2^{X} (Wh_{DX})}{\sum_2^{X1} (Wh_{IX})} \right) \right) \tag{7-1}$$

where X is the number of test repeats; WhDi is the electrical energy in watt-hours at rated power kilowatts or the electrical equivalent in Wh of thermal energy delivered (output) by the system measured and recorded as WhDi, where i is the cycle number; and WhIi is the Watt hour input (AC) into the system during system charging, including all parasitic losses, measured and recorded as WhIi, where i is the cycle number.

7.4.2 Duty-Cycle Roundtrip Efficiency Measurement for Peak-Shaving Applications. The manufacturer shall select an intended application and apply the duty cycle as provided in Section 5.1.3. In conducting the tests required in Section 5.1, the charge and discharge of the ESS shall be in accordance with this section using the duty cycle in Section 5.1.3.

1. The ESS shall be fully charged in accordance with the manufacturer's specifications. The system shall be brought to the initial desired SOC as dictated by a given $V_{initial}$, $T_{initial}$, or $P_{initial}$ in accordance with duty-cycle A as provided in Section 5.1.3 by removing the necessary amount of charge at the rated power of the ESS as provided by the manufacturer's specifications. The ESS shall be held at that voltage (V) corresponding to the initial SOC, temperature (T) corresponding to the initial SOC or mass percentage of the relevant phase (P) corresponding to the initial SOC for at least 10 but not more than 30 minutes. Alternatively, the system shall be permitted to be brought directly to the desired initial SOC by charging or discharging the ESS to the desired $V_{initial}$, $T_{initial}$, or $P_{initial}$ at rated power and held at that V, T, or P for at least 10 but not more than 30 minutes.
2. The ESS shall then be subjected to the duty cycle as described in Section 5.1.3.
3. At the end of the duty cycle, the ESS shall be returned to the initial SOC as dictated by a given $V_{initial}$, $T_{initial}$, or $P_{initial}$ by charging or discharging the ESS at rated power and holding at that voltage (V), temperature (T), or mass percentage of the relevant phase (P) for at least 10 but not more than 30 minutes.
4. Steps 1 through 3 shall be repeated for duty cycles B and then C as described in Section 5.1.3 using the same amount of time the ESS is held at initial SOC in applying duty-cycle A.
5. The duty-cycle roundtrip efficiency at each discharge power of each duty cycle shall be determined by dividing the energy removed (output) from the ESS at a given power by the energy required to recharge (input) the ESS.

The duty-cycle roundtrip efficiency as a function of discharge power shall be determined by dividing the energy removed from the ESS at a given power by the energy required to recharge the ESS.

At the end of the test, the ESS shall be brought to a full SOC using a procedure recommended by the manufacturer's specifications and operating instructions.

7.4.3 Duty-Cycle Roundtrip Efficiency Measurement for Frequency-Regulation Applications. The manufacturer shall apply the duty cycle as provided in Section 5.2.2. In conducting the tests required in Section 5.2, the charge and discharge of the ESS shall be in accordance with the duty cycle described in Section 5.2.2.

1. The ESS shall be fully charged in accordance with the manufacturer's specifications. The system shall be brought to the initial desired SOC as dictated by a given $V_{initial}$ in accordance with the duty cycle described in Section 5.2.2 by removing the necessary amount of charge at the rated power of the ESS as provided by the manufacturer's specifications. The ESS shall be held at that voltage (V) corresponding to the initial SOC for at least 10 but no more than 30 minutes. Alternatively, the system shall be permitted to be brought directly to the desired initial SOC by charging or discharging the ESS to the desired $V_{initial}$ at rated power and held at that V or T for at least 10 but no more than 30 minutes.
2. The ESS shall then be subjected to the duty cycle as described in Section 5.2.2.
3. At the end of the duty cycle, the ESS shall be returned to the initial SOC as dictated by a given $V_{initial}$ by charging or discharging at rated power and holding at that voltage (V) for at least 10 but no more than 30 minutes.
4. The duty-cycle roundtrip efficiency shall be determined by dividing the energy removed (output) from the ESS by the energy required to recharge (input) the ESS.

The duty-cycle roundtrip efficiency as a function of discharge power shall be determined by dividing the energy removed from the ESS at a given power by the energy required to recharge the ESS. The ESS EMS shall track the maximum SOC and minimum SOC during the duty cycle by integrating the current with respect to time.

At the end of the test, the ESS shall be brought to a full SOC using a procedure as recommended by the manufacturer's specifications and operating instructions.

7.4.4 Duty-Cycle Roundtrip Efficiency Measurement for Islanded Microgrid Applications. The manufacturer shall apply the three duty cycles as provided in Section 5.3.2. In conducting the tests required in Section 5.1, the charge and discharge of the ESS shall be in accordance with this section using the three duty cycles in Section 5.3.2.

1. The ESS shall be fully charged in accordance with the manufacturer's specifications. The system shall be brought to the initial desired SOC as dictated by a given $V_{initial}$ in accordance with the first duty cycle as provided in Section 5.3.2, by removing the necessary amount of charge at the rated power of the ESS as provided by the manufacturer's specifications. The ESS shall be held at that voltage (V) corresponding to the initial SOC for at least 10 but not more than 30 minutes. Alternatively, the system shall be permitted to be brought directly to the desired initial SOC by charging or discharging the ESS to the desired $V_{initial}$ at rated power and held at that voltage (V) for at least 10 but not more than 30 minutes.

2. The ESS shall then be subjected to the first duty cycle as described in Section 5.3.2.
3. At the end of the duty cycle, the ESS shall be returned to the initial SOC as dictated by a given $V_{initial}$ by charging or discharging the ESS at rated power and holding at that voltage (V) for at least 10 but not more than 30 minutes.
4. Steps 1 through 3 shall be repeated for the second and third duty cycles as described in Section 5.3.2 using the same amount of time the ESS is held at initial SOC in applying the first duty cycle.
5. The duty-cycle roundtrip efficiency at each discharge power of each of the three duty cycles shall be determined by dividing the energy removed (output) from the ESS at a given power by the energy required to recharge (input to) the ESS.

The duty-cycle roundtrip efficiency as a function of discharge power shall be determined by dividing the energy removed from the ESS at a given power by the energy required to recharge the ESS.

At the end of the test, the ESS shall be brought to a full SOC using a procedure recommended by the manufacturer's specifications and operating instructions.

7.4.5 Reference Signal Tracking (Frequency Regulation and Islanded Microgrids). The ability of the ESS to respond to a reference signal shall be recorded during the RTE test. The sum of the square of errors between the balancing signal (Psignal) and the power delivered or absorbed by the ESS (Pess) shall be calculated in accordance with Equation 7-2 and used to estimate the inability of the ESS to track the signal.

$$\Sigma\ (\text{Psignal} - \text{Pess})^2 \qquad (7\text{-}2)$$

where Psignal is the balancing signal and Pess is ESS power (watts).

The measurements shall be taken at every point in time that the ESS receives a change in the balancing signal. The sum of the absolute magnitude of the difference between the balancing signal and ESS power shall be calculated in accordance with Equation 7-3.

$$\Sigma|\text{Psignal} - \text{Pess}| \qquad (7\text{-}3)$$

where Psignal is the balancing signal and Pess is ESS power (watts).

The sum of the absolute magnitude of the difference between the balancing signal energy and ESS energy shall be calculated in accordance with Equation 7-4 and reported by the manufacturer of the ESS to account for the inability for the ESS to follow the signal due to the ESS reaching the SOC limits provided in the manufacturer's specifications and operating instructions.

$$\Sigma|\text{Esignal} - \text{Eess}| \qquad (7\text{-}4)$$

where Esignal is the signal energy for a half-cycle, with half-cycle being the signal of the same sign (above or below the x-axis), and Eess is the energy supplied to or absorbed by the ESS for each half-cycle.

The total time the ESS cannot follow the signal and percentage tracked where (Psignal – Pess)/Psignal is less than 0.02 shall be determined in accordance with Equation 7-5.

When |(Psignal-Pess)/Psignal| is less than 0.02, the ESS shall be considered to track the signal. The percentage of time the signal is tracked during the 24-hour period of the duty cycle provided in Section 5.2.2 shall be determined in accordance with Equation 7-5.

$$\%\text{ of time signal is tracked} = [\text{Time signal is tracked (h)}/24\text{ h}] \times 100 \qquad (7\text{-}5)$$

7.5 Response Time and Ramp Rate Test. The ESS shall have a response time and ramp rate test performed in accordance with this section to determine the amount of time required for the ESS output to transition from no discharge to full discharge rate and from no charge to full charge rate.

7.5.1 Test Overview. The method for measuring ramp rate shall be the same for all ESSs regardless of application. The manufacturer shall provide information about rated power as required by the provisions in Section 5.1 or 5.2.

The response time shall be measured in accordance with Figure 7.5.1 starting when the signal (command) is received at the ESS boundary as established in Section 4.2 and continuing until the ESS discharge power output (electrical or thermal) reaches 100 ± 2% of its rated power.

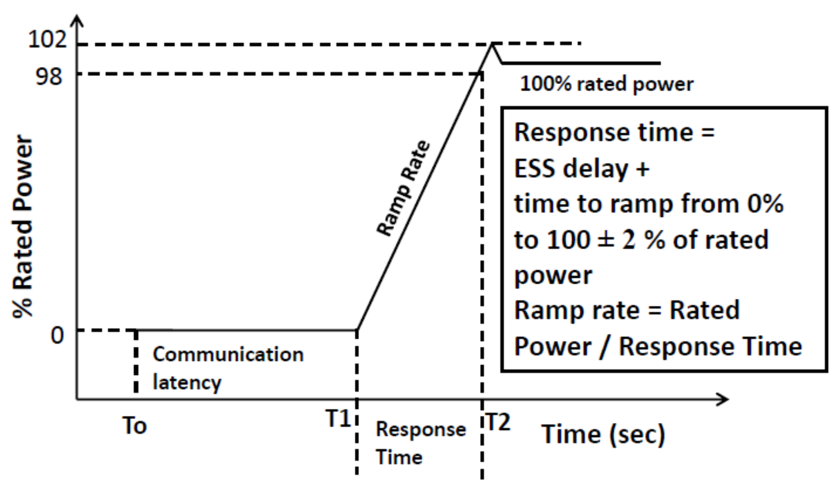

Figure 7.5.1. Response Time Test

7.5.2 Discharge Test Routine. The discharge response time test shall be conducted in accordance with the following procedure and the discharge response time calculated in accordance with Equation 7-6.

1. The ESS shall be at the 50% SOC and in an active standby state.
2. The data acquisition system (DAS) shall be configured to record a time stamp T_0 when a change in set point from rest to a discharge output command is sent to the ESS.
3. The DAS shall be configured to record a time stamp T_1 when the ESS starts responding to the discharge command signal. .
4. The DAS shall be configured to record a time stamp T_2 when the output of the ESS reaches 100 ±2% of its rated power capacity. The acquisition rate of data shall be at least twice as fast as the

rated power capacity divided by the discharge ramp rate of the ESS, as determined in accordance with Equation 7-7a, and at least one intermediate data point shall be acquired as the ESS transitions from rest to full discharge.

5. The ESS shall be configured to respond to a step change in power output set point according to the ESS manufacturer's specifications.
6. The DAS shall be started and shall command to change the power output of the ESS to full rated discharge power output, and $T_1$and T2 shall be measured and recorded.
7. The DAS shall be reset to a state to begin recording data and the ESS placed in a state of active standby.

$$RTD = T2 - T1 \tag{7-6}$$

where RTD is the discharge response time in seconds; T1 is the beginning time stamp, in seconds, when the ESS starts responding to the discharge signal; and T2 is the end time stamp, in seconds, when the output of the ESS reaches 100 ±2 % of its rated power output.

The discharge ramp rate RR_D shall be calculated in accordance with Equation 7-7a and expressed in megawatts per minute.

$$RR_D = [P_{T2}]/[T_2 - T_1] \times 60 \tag{7-7a}$$

where P_{T2} is the power output of the ESS recorded at time T_2(100 ±2% of rated power capacity); T_1 is the beginning time stamp, in seconds, when the ESS starts responding to the discharge signal; and T_2 is the end time stamp, in seconds, when the output of the ESS reaches 100 ±2% of its rated power output.

The discharge ramp rate shall also be expressed as percent rated power per minute (R_{R_pct},) in accordance with Equation 7-6b.

$$R_{Rpct} = RR_D / P_R \times 100 \tag{7-6b}$$

where P_R is the rated power of the ESS.

7.5.3. Charge Test Routine. The charge response time test shall be conducted in accordance with the following procedure and the charge response time calculated in accordance with Equation 7-8.

1. The ESS shall be at the 50% SOC and in an active standby state.
2. The DAS shall be configured to record a time stamp T_0 when a change in set point from rest to a charge output command is sent to the ESS.
3. The DAS shall be configured to record a time stamp T_1 when the ESS starts responding to the charge command signal.
4. The DAS shall be configured to record a time stamp T_2 when the input to the system reaches a 100 ±2% of its rated power capacity. The acquisition rate of data shall be at least twice as fast as the rated power capacity divided by the ramp rate of the ESS, as determined in accordance with Equation 7-9a, and at least one intermediate data point shall be acquired as the ESS transitions from rest to full charge.

5. The ESS shall be configured to respond to a step change in power input set point according to the ESS specifications provided by the manufacturer.
6. The DAS shall be started and shall command to change the power input to the ESS to full rated charge power input, and T_1 and T_2 shall be measured and recorded.
7. The DAS shall be reset to a state to begin recording data and the ESS placed in a state of active standby.

$$RT_C = T_2 - T_1 \qquad (7\text{-}8)$$

where RT_C is the charge response time in seconds; T_1 is the beginning time stamp, in seconds, when the ESS starts responding to the charge signal; and T_2 is the end time stamp, in seconds, when the input to the ESS reaches 100 ±2 % of its rated power output.

The charge ramp rate RR shall be calculated in accordance with Equation 7-9a and expressed in megawatts per minute.

$$RR_C = [P_{T2}]/[T_2 - T_1] \times 60 \qquad (7\text{-}9a)$$

where P_{T2} is the power input to the ESS recorded at time T_2 (100 ±2% of rated power capacity).

The charge ramp rate shall also be expressed as percent rated power per minute (RRC_{pct}) in accordance with Equation 7-9b.

$$RRC_{pct} = RRC/ PR \times 100 \qquad (7\text{-}9b)$$

where PR is the rated power of the ESS.

7.6 State-of-Charge Excursions. The SOC of the ESS during testing required under the protocol shall be monitored and continuously updated by integrating the current with respect to time for each half-cycle. For the purpose of this requirement a half-cycle shall be considered the amount of time when the current or power is of the same sign. The integrated area shall be added to the SOC as the charge half-cycle is started or subtracted from the prior SOC as the discharge cycle is started. The state-of-charge excursion shall be reported in accordance with the provisions in Section 8.2.5.

7.7 Energy Capacity Stability. The energy capacity stability of the ESS shall be determined by dividing the stored energy capacity by the initial stored energy capacity of the ESS. Stored energy capacity shall be determined in accordance with Section 7.3. The initial capacity stability of an ESS serving a peak-shaving application shall be determined before and after the 72-hour duty cycle and reported in accordance with the provisions in Section 8.1.4. The initial capacity stability of an ESS serving a frequency-regulation application shall be determined before and after the 24-hour duty cycle and reported in accordance with the provisions in Section 8.2.6.

8.0 Reporting Performance Results

8.1 Peak-Shaving (management) Applications. The performance of an ESS intended for a peak-shaving application shall be reported by the manufacturer of the system in accordance with the provisions in Sections 8.1.1 through 8.1.5 as determined in accordance with the applicable provisions of Section 7.0. In addition, the classification(s) of the ESS shall be reported in accordance with the provisions in Section 5.1.1.

8.1.1 System Stored Energy Capacity and Roundtrip Efficiency. The stored energy capacity of the ESS determined in accordance with the provisions in Section 7.3 and the RTE determined in accordance with the provisions in Section 7.4.1 shall be reported as provided in Table 8.1.1. Where additional testing is performed beyond the minimum required two cycles, an additional row shall be added for each cycle and the total charge and discharge energy shall be the sum of all values reported and the RTE based on those totals.

Table 8.1.1. Stored Energy Capacity and Roundtrip Efficiency at Rated Power

	Charge Energy (Wh)	Discharge Energy (Wh)	Roundtrip Efficiency
Cycle 1	______	______	
Cycle 2	______	______	
Sum			

8.1.2 Duty-Cycle Roundtrip Efficiency. The duty-cycle roundtrip efficiency shall be reported together with respect to discharge power and to the discharge duration based on the data collected in accordance with the provisions in Section 7.4.2. Table 8.1.2 shall be used to report the measured charge and discharge power and charge and discharge energy of the ESS, the percent of rated power during discharge and the ESS duty-cycle roundtrip efficiency. The information in Table 8.1.2 shall also be provided in a graphical form, with the x-axis being the percentage rated power during discharge and the y-axis being the duty cycle roundtrip efficiency.

Table 8.1.2. Duty-Cycle Roundtrip Efficiency

Duty Cycle	Charge Time (h)	Charge Power (kW)	Charge Energy[(a)](kWh)	Discharge Time (h)	Discharge Power (kW)	Discharge Energy (kWh)[(a)]	% Rated Power During Discharge	Duty-Cycle Roundtrip efficiency
A	12			6				
B	12			4				
C	12			2				

(a) The charge and discharge energy includes energy to bring the ESS back to initial SOC after each duty cycle.

8.1.3 Response Time and Ramp Rate. The response times in seconds and ramp rates in megawatts per minute of the ESS shall be reported as determined in accordance with the provisions in Section 7.5 as follows:

Discharge response time = -----seconds

Discharge ramp rate = ------- MW/min and --------% rated power/min

Charge response time = -----seconds

Charge ramp rate = ------- MW/min and -------% rated power/min.

8.1.4 Energy Capacity Stability. The energy capacity stability of the ESS shall be reported as a percent of initial performance as determined in accordance with Section 7.7 along with the date of the test upon which the reported value is based and the ambient temperature and barometric pressure during the test.

8.1.5 Power Factor. The power factor of any inverter supplied as a component of the ESS shall be reported as a dimensionless number PF between -1 and +1.

8.2 Frequency-Regulation Applications. The performance of an ESS intended for a frequency-regulation application shall be reported by the manufacturer in accordance with the provisions in Sections 8.2.1 through 8.2.7 as determined in accordance with the applicable provisions of Section 7.0.

8.2.1 System Stored Energy Capacity and Roundtrip Efficiency. The stored energy capacity of the ESS, as determined in accordance with the provisions in Section 7.3, and the RTE, as determined in accordance with the provisions in Section 7.4.1, shall be reported as shown in Table 8.1.1.

8.2.2 Duty-Cycle Roundtrip Efficiency. The duty-cycle roundtrip efficiency shall be reported together with respect to peak discharge power divided by the energy of the ESS and to the discharge duration based on the data collected in accordance with the provisions in Section 7.4.3.

8.2.3 Response Time and Ramp Rate. The response time in seconds and ramp rate in megawatts per minute of the ESS shall be reported in accordance with Section 8.1.3 as determined in accordance with the provisions in Section 7.5.

8.2.4 Reference Signal Tracking. The reference signal tracking of the ESS shall be reported in accordance with the provisions in Section 7.4.5 as follows:

$\Sigma\ (Psignal - Pess)^2 =$

$\Sigma|Psignal - Pess| =$

$\Sigma|Esignal - Eess| =$

% of time signal is tracked =.

8.2.5 State-of-Charge Excursion. The state-of-charge excursion shall be reported as determined in accordance with the provisions in Section 7.6 along with the date of the test upon which the reported value is based and the ambient temperature and barometric pressure during the test.

Lowest SOC –

Highest SOC –

8.2.6 Energy Capacity Stability. The capacity stability of the ESS shall be reported as a percent of initial performance as determined in accordance with the provisions in Section 7.7 along with the date of the test upon which the reported value is based and the ambient temperature and barometric pressure during the test.

8.2.7 Power Factor. The power factor of any inverter supplied as a component of the ESS shall be reported as a dimensionless number PF between -1 and +1.

8.3 Islanded Microgrid Applications. The performance of an ESS intended for an islanded microgrid application shall be reported by the manufacturer of the ESS in accordance with the provisions in Sections 8.3.1 through 8.3.7 as determined in accordance with the applicable provisions of Section 7.0.

8.3.1 System Stored Energy Capacity and Roundtrip Efficiency. The stored energy capacity of the ESS determined in accordance with the provisions in Section 7.3 and the RTE as determined in accordance with the provisions in Section 7.4.1 shall be reported as shown in Table 8.1.1. Where additional testing is performed beyond the minimum required two cycles, an additional row shall be added for each cycle and the total charge and discharge energy shall be the sum of all values reported and the roundtrip efficiency shall be based on those totals.

8.3.2 Duty-Cycle Roundtrip Efficiency. The duty-cycle roundtrip efficiency shall be reported as a function of discharge power and discharge duration based on the data collected in accordance with the provisions in Section 7.4.4. Table 8.3.2 shall be used to report the measured charge and discharge energy of the ESS and the ESS duty-cycle roundtrip efficiency.

Table 8.3.2. Roundtrip Efficiency Test for Microgrid Duty Cycles

Duty Cycle	Charge Energy (Wh)	Discharge Energy (Wh)	Duty Cycle Roundtrip Efficiency
First			
Second			
Third			

Note that the charge and discharge energy values include energy to bring the ESS back to initial state of charge after each duty cycle.

8.3.3 Response Time and Ramp Rate. The response time in seconds and ramp rate in megawatts per minute of the ESS shall be reported in accordance with Section 8.1.3 as determined in accordance with the provisions in Section 7.5.

8.3.4 Reference Signal Tracking. The reference signal tracking of the ESS shall be reported as shown in Table 8.3.4 as determined in accordance with the provisions in Section 7.4.5.

Table 8.3.4. Reference Signal Tracking Test for Microgrid Duty Cycles

Duty Cycle	$\Sigma(P_{signal} - P_{ess})^2$ (watts^2)	$\Sigma\|P_{signal} - P_{ess}\|$ (watts)	$\Sigma\|E_{signal} - E_{ess}\|$ = (Wh)	% of time signal is tracked
First				
Second				
Third				

8.3.5 State-of-Charge Excursion. The state-of-charge excursion for each duty cycle shall be reported as determined in accordance with the provisions in Section 7.6 along with the date of the test upon which the reported value is based and the ambient temperature and barometric pressure during the test.

Lowest SOC, renewables with frequency regulation –

Highest SOC, renewables with frequency regulation –

Lowest SOC, renewables without frequency regulation –

Highest SOC, renewables without frequency regulation –

Lowest SOC, no renewables and no frequency regulation –

Highest SOC, no renewables and no frequency regulation –

8.3.6 Energy Capacity Stability. The capacity stability of the ESS shall be reported as a percentage of initial performance as determined in accordance with the provisions in Section 7.7 along with the date of the test upon which the reported value is based and the ambient temperature and barometric pressure during the test.

8.3.7 Power Factor. The power factor of any inverter supplied as a component of the ESS shall be reported as a dimensionless number, PF, between –1 and +1.

9.0 Referenced Standards

9.1 Institute of Electrical and Electronics Engineers (IEEE) Standard 1679-2010. IEEE Recommended Practice for the Characterization and Evaluation of Emerging Energy Storage Technologies in Stationary Applications.

9.2 American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) Standard 105-2014. ANSI/ASHRAE Standard Methods of Determining, Expressing, and Comparing Building Energy Performance.

9.3 Institute of Electrical and Electronics Engineers (IEEE) Standard 1459-2010. IEEE Standard Definitions for the Measurement of Electric Power Quantities Under Sinusoidal, Nonsinusoidal, Balanced, or Unbalanced Conditions.

10.0 References

[1] IEEE (Institute of Electrical and Electronics Engineers) Standard 1679-2010, "Recommended Practice for the Characterization and Evaluation of Emerging Energy Storage Technologies in Stationary Applications." New York.

[2] Eyer J, J Iannucci, and G Corey. 2004. *Energy Storage Benefits and Market Analysis Handbook*. SAND2004-6177, Sandia National Laboratories, Albuquerque, New Mexico.

[3] Eyer J and G Corey. 2010. *Energy Storage for the Electricity Grid: Benefits and Market Potential Assessment Guide*. SAND2010-0815, Sandia National Laboratories, Albuquerque, New Mexico.

[4] Conover DR and VV Viswanathan. 2014. *Determination of the Duty Cycle for Energy Storage Systems Integrated with a Microgrid*. PNNL-23390, Pacific Northwest National Laboratory, Richland, Washington.

Normative Appendix A

Duty-Cycle Signal for Frequency-Regulation Applications of Energy Storage Systems

Normative Appendix A

Duty-Cycle Signal for Frequency-Regulation Applications of Energy Storage Systems

In determining the duty cycle, the PJM balancing signal for the period April 1, 2011 through March 31, 2012 was analyzed.[1] The standard deviation over a 24-hour period was used as a metric for the aggressiveness of the signal. The signals were grouped into low, average, and high standard deviation days. A representative 2-hour average standard deviation signal was chosen, and a representative 2-hour high standard deviation signal was chosen. It was also noted that 24-hour signals were energy neutral. The average and high standard deviation signals were chosen such that they were energy neutral and had the same standard deviation as the average and high deviation signals. The duty cycle consisted of three 2-hour average signals, followed by one 2-hour high deviation signal, three 2-hour average signals, one 2-hour high deviation signal, and four 2-hour average signals.

Data in the following tables are the bases for a duty-cycle graphic presented in Section 5.2.3.

Example Statistics	Standard Deviation	Sum of Signal	Time at 1 (sec)	Time at 1 (sec)	% Time at 1	% Time at -1
Average Profile	0.361	-0.00065	0	0	0	0
Aggressive Signal	0.460	0.00175	164	132	2.28	1.83

Reference Statistics	Lowest Day	Ave Day #1	Ave Day #2	Ave Day #3	Highest Day
Standard Deviation	0.132	0.334	0.332	0.333	0.451

Duty Cycle
3 Average
1 Aggressive
3 Average
1 Aggressive
4 Average

[1] http://www.pjm.com/markets-and-operations/ancillary-services/mkt-based-regulation.aspx

Time	Average Signal	Aggressive Signal	Time	Average Signal	Aggressive Signal	Time	Average Signal	Aggressive Signal
0:00:00	-0.144251049	-0.282695264	**0:00:40**	-0.08397799	-0.18872872	**0:01:20**	-0.017526021	0.050382435
0:00:04	-0.129648238	-0.273952544	**0:00:44**	-0.054430272	-0.179451689	**0:01:24**	-0.018916732	0.070937358
0:00:08	-0.136013523	-0.265209794	**0:00:48**	-0.032121196	-0.170174643	**0:01:28**	-0.007483151	0.091492288
0:00:12	-0.142378807	-0.256467074	**0:00:52**	-0.009812118	-0.164905593	**0:01:32**	0.003950429	0.096228711
0:00:16	-0.148744106	-0.247724339	**0:00:56**	0.00501351	-0.159636542	**0:01:36**	0.016937084	0.100965127
0:00:20	-0.155109391	-0.2383544	**0:01:00**	0.012355687	-0.139434874	**0:01:40**	0.030441433	0.101237461
0:00:24	-0.161474675	-0.228357255	**0:01:04**	0.019697864	-0.104300603	**0:01:44**	0.043945782	0.097045712
0:00:28	-0.150013253	-0.218360111	**0:01:08**	0.005642735	-0.069166332	**0:01:48**	0.065859124	0.092853956
0:00:32	-0.138551846	-0.208362967	**0:01:12**	-0.008412393	-0.025457811	**0:01:52**	0.087772466	0.087061487
0:00:36	-0.113525704	-0.198365822	**0:01:16**	-0.016135313	0.018250709	**0:01:56**	0.102681331	0.081269011
0:02:00	0.115255378	0.077279635	**0:05:08**	-0.141811341	0.553776085	**0:08:16**	0.149056494	0.754771113
0:02:04	0.127829418	0.075093359	**0:05:12**	-0.171328619	0.570581317	**0:08:20**	0.179620102	0.737595737
0:02:08	0.136286065	0.072907083	**0:05:16**	-0.19213371	0.587386549	**0:08:24**	0.21018371	0.716852129
0:02:12	0.144742712	0.071547456	**0:05:20**	-0.210034728	0.60419178	**0:08:28**	0.226593435	0.69610852
0:02:16	0.168096304	0.070187822	**0:05:24**	-0.227935746	0.620996952	**0:08:32**	0.243003175	0.673140526
0:02:20	0.206346855	0.065275341	**0:05:28**	-0.252165616	0.63694191	**0:08:36**	0.260151565	0.650172532
0:02:24	0.24459739	0.056809999	**0:05:32**	-0.27639544	0.650305927	**0:08:40**	0.278038591	0.625315309
0:02:28	0.286141574	0.048344657	**0:05:36**	-0.296143562	0.663669944	**0:08:44**	0.295925617	0.598568857
0:02:32	0.327685773	0.04501012	**0:05:40**	-0.31140995	0.677338839	**0:08:48**	0.345791727	0.571822405
0:02:36	0.371769905	0.041675579	**0:05:44**	-0.326676309	0.691312611	**0:08:52**	0.395657867	0.540236712
0:02:40	0.41839397	0.041155186	**0:05:48**	-0.336338639	0.705286384	**0:08:56**	0.416477412	0.508651018
0:02:44	0.464600265	0.043448932	**0:05:52**	-0.346000969	0.719260216	**0:09:00**	0.427614808	0.475282341
0:02:48	0.509553194	0.045742679	**0:05:56**	-0.354167581	0.733233988	**0:09:04**	0.438752174	0.440130711
0:02:52	0.554506123	0.053398695	**0:06:00**	-0.361835599	0.745755792	**0:09:08**	0.484879583	0.40497905
0:02:56	0.602924347	0.06105471	**0:06:04**	-0.369503617	0.756825626	**0:09:12**	0.531006992	0.368054479
0:03:00	0.654807866	0.070469923	**0:06:08**	-0.382226527	0.767895401	**0:09:16**	0.564311445	0.331129909
0:03:04	0.706691384	0.081644334	**0:06:12**	-0.394949466	0.770347893	**0:09:20**	0.584792912	0.294205308
0:03:08	0.720910609	0.092818744	**0:06:16**	-0.413662046	0.772800386	**0:09:24**	0.605274379	0.257280737
0:03:12	0.735129833	0.1054141	**0:06:20**	-0.438364327	0.771793187	**0:09:28**	0.625755847	0.220356166
0:03:16	0.737693191	0.118009456	**0:06:24**	-0.463066578	0.767326355	**0:09:32**	0.646237314	0.184814364
0:03:20	0.728600562	0.129463658	**0:06:28**	-0.491415203	0.762859464	**0:09:36**	0.653857112	0.149272561
0:03:24	0.719507933	0.139776722	**0:06:32**	-0.519763827	0.758392572	**0:09:40**	0.648615301	0.115076534
0:03:28	0.697333694	0.150089785	**0:06:36**	-0.535574436	0.753925741	**0:09:44**	0.643373489	0.082226284
0:03:32	0.662077785	0.155796483	**0:06:40**	-0.53884691	0.74991554	**0:09:48**	0.618583143	0.049376033
0:03:36	0.616101444	0.161503181	**0:06:44**	-0.542119443	0.74636209	**0:09:52**	0.593792737	-0.037982456
0:03:40	0.559404731	0.166243717	**0:06:48**	-0.525878966	0.74280864	**0:09:56**	0.579453528	-0.125340939
0:03:44	0.502707958	0.170018077	**0:06:52**	-0.509638429	0.772468626	**0:10:00**	0.568597972	-0.255351096
0:03:48	0.434835255	0.173792437	**0:06:56**	-0.485117942	0.802128613	**0:10:04**	0.557742417	-0.428012878
0:03:52	0.366962582	0.259592712	**0:07:00**	-0.452317476	0.808736086	**0:10:08**	0.534055412	-0.600674689
0:03:56	0.299703628	0.345392972	**0:07:04**	-0.41951701	0.792291105	**0:10:12**	0.510368407	-0.702175319
0:04:00	0.233058423	0.409059495	**0:07:08**	-0.398959488	0.775846064	**0:10:16**	0.484838426	-0.80367589
0:04:04	0.166413218	0.450592279	**0:07:12**	-0.378401995	0.776005566	**0:10:20**	0.45746544	-0.875576496
0:04:08	0.126902997	0.492125064	**0:07:16**	-0.360686213	0.776165128	**0:10:24**	0.430092424	-0.917877018
0:04:12	0.087392792	0.492103755	**0:07:20**	-0.345812142	0.778602719	**0:10:28**	0.406610578	-0.9601776
0:04:16	0.062752046	0.492082447	**0:07:24**	-0.330938071	0.78331846	**0:10:32**	0.383128703	-0.965281844

Time	Average Signal	Aggressive Signal	Time	Average Signal	Aggressive Signal	Time	Average Signal	Aggressive Signal
0:04:20	0.052980773	0.490190148	**0:07:28**	-0.311509281	0.788034201	**0:10:36**	0.355775058	-0.970386088
0:04:24	0.043209501	0.48642692	**0:07:32**	-0.292080462	0.792749882	**0:10:40**	0.324549615	-0.967141032
0:04:28	0.031373527	0.482663661	**0:07:36**	-0.264012247	0.797465622	**0:10:44**	0.293324172	-0.955546677
0:04:32	0.019537557	0.480816096	**0:07:40**	-0.227304593	0.800635874	**0:10:48**	0.249806523	-0.943952382
0:04:36	0.001462346	0.478968501	**0:07:44**	-0.190596953	0.802260756	**0:10:52**	0.206288859	-0.924059927
0:04:40	-0.022852104	0.480422795	**0:07:48**	-0.151647434	0.803885579	**0:10:56**	0.163547352	-0.904167473
0:04:44	-0.047166552	0.485178918	**0:07:52**	-0.112697922	0.802513361	**0:11:00**	0.121064566	-0.882113814
0:04:48	-0.057434734	0.48993507	**0:07:56**	-0.07070902	0.801141083	**0:11:04**	0.078581773	-0.85789907
0:04:52	-0.067702919	0.500819147	**0:08:00**	-0.02568073	0.796761096	**0:11:08**	0.03163211	-0.833684206
0:04:56	-0.080728419	0.511703193	**0:08:04**	0.019347558	0.789373279	**0:11:12**	-0.015317554	-0.809469461
0:05:00	-0.09651123	0.524471402	**0:08:08**	0.066808105	0.781985462	**0:11:16**	-0.035845049	-0.785254598
0:05:04	-0.112294048	0.539123714	**0:08:12**	0.114268646	0.768378317	**0:11:20**	-0.047565155	-0.761400461
0:11:24	-0.059285261	-0.737906992	**0:14:32**	-0.525780678	-0.029614517	**0:17:40**	0.433162093	0.24098675
0:11:28	-0.081598312	-0.714413524	**0:14:36**	-0.51625663	-0.002600966	**0:17:44**	0.471374691	0.250905424
0:11:32	-0.103911363	-0.690919995	**0:14:40**	-0.515544653	0.021431228	**0:17:48**	0.504213572	0.260824114
0:11:36	-0.133230746	-0.667426527	**0:14:44**	-0.514832675	0.042482067	**0:17:52**	0.537052453	0.27278617
0:11:40	-0.169556454	-0.644908607	**0:14:48**	-0.516575634	0.063532904	**0:17:56**	0.566769838	0.284748197
0:11:44	-0.205882162	-0.623366296	**0:14:52**	-0.518318653	0.079306312	**0:18:00**	0.593365788	0.296710253
0:11:48	-0.249970943	-0.601823986	**0:14:56**	-0.517415941	0.09507972	**0:18:04**	0.619961739	0.308672279
0:11:52	-0.294059724	-0.585796714	**0:15:00**	-0.513867617	0.108115003	**0:18:08**	0.635332823	0.320634335
0:11:56	-0.332335889	-0.569769442	**0:15:04**	-0.510319233	0.118412152	**0:18:12**	0.650703847	0.331750214
0:12:00	-0.36479944	-0.555796027	**0:15:08**	-0.4926458	0.128709301	**0:18:16**	0.674778104	0.342866123
0:12:04	-0.39726299	-0.54387635	**0:15:12**	-0.474972397	0.135443151	**0:18:20**	0.707555532	0.353982002
0:12:08	-0.423568636	-0.531956732	**0:15:16**	-0.457298964	0.142177001	**0:18:24**	0.740332961	0.36509791
0:12:12	-0.449874282	-0.5225811	**0:15:20**	-0.439625561	0.14891085	**0:18:28**	0.718795717	0.376213789
0:12:16	-0.468467623	-0.513205469	**0:15:24**	-0.421952128	0.1556447	**0:18:32**	0.697258472	0.385999918
0:12:20	-0.4793486	-0.503829837	**0:15:28**	-0.400327325	0.16237855	**0:18:36**	0.699237406	0.395786077
0:12:24	-0.490229607	-0.494454175	**0:15:32**	-0.378702521	0.169112399	**0:18:40**	0.724732518	0.404150993
0:12:28	-0.50880307	-0.485078543	**0:15:36**	-0.357551008	0.175846249	**0:18:44**	0.75022769	0.411094725
0:12:32	-0.527376473	-0.479038358	**0:15:40**	-0.336872816	0.181683719	**0:18:48**	0.758759141	0.418038458
0:12:36	-0.545949936	-0.472998172	**0:15:44**	-0.316194624	0.18662481	**0:18:52**	0.767290592	0.402234495
0:12:40	-0.564523339	-0.46839875	**0:15:48**	-0.270259708	0.191565886	**0:18:56**	0.772988915	0.386430532
0:12:44	-0.580560088	-0.465240091	**0:15:52**	-0.224324822	0.179199785	**0:19:00**	0.777742863	0.389041275
0:12:48	-0.588986754	-0.462081432	**0:15:56**	-0.180791527	0.166833684	**0:19:04**	0.78249687	0.410066783
0:12:52	-0.597413361	-0.518998981	**0:16:00**	-0.138058767	0.168021813	**0:19:08**	0.767407358	0.431092262
0:12:56	-0.604643404	-0.575916529	**0:16:04**	-0.095325999	0.182764143	**0:19:12**	0.752317786	0.438400149
0:13:00	-0.610676885	-0.614979267	**0:16:08**	-0.056056872	0.197506472	**0:19:16**	0.729599118	0.445708007
0:13:04	-0.616710365	-0.636187255	**0:16:12**	-0.016787743	0.207903773	**0:19:20**	0.699251235	0.446326166
0:13:08	-0.622743845	-0.657395244	**0:16:16**	0.015659085	0.218301073	**0:19:24**	0.668903351	0.440254569
0:13:12	-0.628777325	-0.640126348	**0:16:20**	0.041283615	0.222491622	**0:19:28**	0.625755668	0.434182972
0:13:16	-0.645559728	-0.622857392	**0:16:24**	0.066908143	0.22047545	**0:19:32**	0.582608044	0.420326501
0:13:20	-0.673091054	-0.60193038	**0:16:28**	0.067889266	0.218459263	**0:19:36**	0.549489439	0.406470001
0:13:24	-0.700622439	-0.577345192	**0:16:32**	0.068870381	0.211035207	**0:19:40**	0.52639991	0.389910698
0:13:28	-0.725902319	-0.552760065	**0:16:36**	0.077603571	0.20361115	**0:19:44**	0.503310382	0.370648563
0:13:32	-0.751182139	-0.5223068	**0:16:40**	0.094088838	0.196187079	**0:19:48**	0.476496965	0.351386428
0:13:36	-0.763730168	-0.491853565	**0:16:44**	0.110574104	0.188763022	**0:19:52**	0.449683547	0.329670012
0:13:40	-0.763546348	-0.458480835	**0:16:48**	0.136972636	0.181338966	**0:19:56**	0.416702598	0.307953626

Time	Average Signal	Aggressive Signal	Time	Average Signal	Aggressive Signal	Time	Average Signal	Aggressive Signal
0:13:44	-0.763362527	-0.42218861	**0:16:52**	0.163371146	0.179294288	**0:20:00**	0.377554119	0.285160273
0:13:48	-0.741654694	-0.385896415	**0:16:56**	0.185547948	0.17724961	**0:20:04**	0.338405669	0.261289984
0:13:52	-0.719946861	-0.349604219	**0:17:00**	0.203503013	0.178608507	**0:20:08**	0.293863147	0.23741971
0:13:56	-0.693281531	-0.313311994	**0:17:04**	0.221458077	0.183370993	**0:20:12**	0.249320656	0.20944871
0:14:00	-0.661658645	-0.278122306	**0:17:08**	0.254830331	0.188133478	**0:20:16**	0.21532847	0.181477711
0:14:04	-0.630035758	-0.24403511	**0:17:12**	0.288202584	0.195357874	**0:20:20**	0.191886604	0.152413338
0:14:08	-0.601230502	-0.209947914	**0:17:16**	0.308368504	0.20258227	**0:20:24**	0.168444753	0.122255579
0:14:12	-0.572425187	-0.178580105	**0:17:20**	0.315328062	0.209177762	**0:20:28**	0.164989516	0.092097826
0:14:16	-0.558908641	-0.147212312	**0:17:24**	0.322287619	0.215144351	**0:20:32**	0.16153428	0.064982533
0:14:20	-0.560680866	-0.116548337	**0:17:28**	0.343709856	0.22111094	**0:20:36**	0.159856126	0.037867244
0:14:24	-0.562453032	-0.086588204	**0:17:32**	0.365132093	0.227077529	**0:20:40**	0.159955084	0.011721895
0:14:28	-0.544116855	-0.056628067	**0:17:36**	0.394949526	0.233044118	**0:20:44**	0.160054043	-0.013453512
0:20:48	0.147964299	-0.038628917	**0:23:56**	0.131035417	-0.600423455	**0:27:04**	-0.074643083	-0.12903069
0:20:52	0.135874569	-0.060118832	**0:24:00**	0.140090451	-0.604626536	**0:27:08**	-0.07545495	-0.106693678
0:20:56	0.123784833	-0.081608742	**0:24:04**	0.149145499	-0.608829558	**0:27:12**	-0.076266818	-0.087153085
0:21:00	0.111695096	-0.100404285	**0:24:08**	0.142941609	-0.613032579	**0:27:16**	-0.073962696	-0.067612492
0:21:04	0.099605359	-0.116505459	**0:24:12**	0.136737719	-0.614885211	**0:27:20**	-0.070619904	-0.049330674
0:21:08	0.079348914	-0.132606626	**0:24:16**	0.139026091	-0.616737843	**0:27:24**	-0.067277111	-0.032307629
0:21:12	0.059092466	-0.144333169	**0:24:20**	0.149806708	-0.616955578	**0:27:28**	-0.087800533	-0.015284582
0:21:16	0.042184882	-0.156059712	**0:24:24**	0.160587341	-0.615538418	**0:27:32**	-0.108323954	0.001738463
0:21:20	0.028626161	-0.166475266	**0:24:28**	0.176043928	-0.614121258	**0:27:36**	-0.112421051	0.018761508
0:21:24	0.015067438	-0.175579831	**0:24:32**	0.191500515	-0.609662473	**0:27:40**	-0.100091837	0.036672246
0:21:28	0.017848149	-0.184684396	**0:24:36**	0.20613879	-0.605203629	**0:27:44**	-0.087762624	0.055470672
0:21:32	0.020628858	-0.191529721	**0:24:40**	0.219958737	-0.599554718	**0:27:48**	-0.068639457	0.074269101
0:21:36	0.02340957	-0.198375061	**0:24:44**	0.2337787	-0.59271574	**0:27:52**	-0.049516298	0.131853893
0:21:40	0.026190279	-0.204115883	**0:24:48**	0.226487219	-0.585876763	**0:27:56**	-0.015746912	0.189438686
0:21:44	0.02897099	-0.208752215	**0:24:52**	0.219195738	-0.574142396	**0:28:00**	0.032668691	0.254576445
0:21:48	0.0401677	-0.213388532	**0:24:56**	0.21029897	-0.56240797	**0:28:04**	0.076313339	0.3272672
0:21:52	0.051364414	-0.276733637	**0:25:00**	0.199796885	-0.557081699	**0:28:08**	0.105645105	0.399957925
0:21:56	0.060832068	-0.340078741	**0:25:04**	0.1892948	-0.558163583	**0:28:12**	0.134976864	0.427090138
0:22:00	0.068570666	-0.41006881	**0:25:08**	0.169691727	-0.559245408	**0:28:16**	0.149961174	0.454222351
0:22:04	0.076309264	-0.486703902	**0:25:12**	0.150088668	-0.558086753	**0:28:20**	0.150598034	0.473012716
0:22:08	0.077436797	-0.563338995	**0:25:16**	0.125954702	-0.556928098	**0:28:24**	0.15123488	0.483461201
0:22:12	0.078564331	-0.593666375	**0:25:20**	0.097289838	-0.553789496	**0:28:28**	0.159465313	0.493909687
0:22:16	0.080322295	-0.623993754	**0:25:24**	0.068624973	-0.548670828	**0:28:32**	0.167695746	0.498898178
0:22:20	0.082710676	-0.643087745	**0:25:28**	0.073609591	-0.54355216	**0:28:36**	0.163605452	0.50388664
0:22:24	0.085099056	-0.650948226	**0:25:32**	0.0785942	-0.534142911	**0:28:40**	0.147194415	0.508875132
0:22:28	0.082506008	-0.658808768	**0:25:36**	0.072992668	-0.524733663	**0:28:44**	0.130783379	0.513863623
0:22:32	0.079912961	-0.657201767	**0:25:40**	0.056804989	-0.514337301	**0:28:48**	0.11437235	0.518852115
0:22:36	0.077319913	-0.655594766	**0:25:44**	0.040617306	-0.502953708	**0:28:52**	0.097961314	0.523523331
0:22:40	0.074726865	-0.652006507	**0:25:48**	0.014631987	-0.491570115	**0:28:56**	0.077557892	0.528194547
0:22:44	0.072133817	-0.646437109	**0:25:52**	-0.011353333	-0.479341418	**0:29:00**	0.055823676	0.530721903
0:22:48	0.057510268	-0.64086771	**0:25:56**	-0.03555176	-0.46711272	**0:29:04**	0.034089461	0.531105459
0:22:52	0.042886719	-0.635298252	**0:26:00**	-0.0579633	-0.453304321	**0:29:08**	0.018564397	0.531488955
0:22:56	0.041184116	-0.629728854	**0:26:04**	-0.080374837	-0.437916219	**0:29:12**	0.003039335	0.513944805
0:23:00	0.052402459	-0.624159396	**0:26:08**	-0.065543331	-0.422528148	**0:29:16**	-0.016027117	0.496400714
0:23:04	0.063620806	-0.618589997	**0:26:12**	-0.050711825	-0.403041691	**0:29:20**	-0.03863496	0.479742289

Time	Average Signal	Aggressive Signal	Time	Average Signal	Aggressive Signal	Time	Average Signal	Aggressive Signal
0:23:08	0.059617702	-0.613020539	**0:26:16**	-0.031836543	-0.383555233	**0:29:24**	-0.0612428	0.463969588
0:23:12	0.055614598	-0.607451141	**0:26:20**	-0.008917488	-0.364068747	**0:29:28**	-0.068343952	0.448196888
0:23:16	0.053781591	-0.601881742	**0:26:24**	0.014001568	-0.344582289	**0:29:32**	-0.075445116	0.442246914
0:23:20	0.054118682	-0.596915305	**0:26:28**	0.002825256	-0.325095832	**0:29:36**	-0.080763765	0.43629691
0:23:24	0.054455772	-0.592551947	**0:26:32**	-0.008351056	-0.305609375	**0:29:40**	-0.084299922	0.434620053
0:23:28	0.052727923	-0.588188529	**0:26:36**	-0.022928152	-0.286122918	**0:29:44**	-0.087836079	0.437216282
0:23:32	0.051000077	-0.586968243	**0:26:40**	-0.040906031	-0.265634239	**0:29:48**	-0.08515963	0.439812541
0:23:36	0.053232357	-0.585747957	**0:26:44**	-0.058883909	-0.244143367	**0:29:52**	-0.08248318	0.447064072
0:23:40	0.059424762	-0.586513758	**0:26:48**	-0.068746246	-0.222652495	**0:29:56**	-0.07980673	0.454315603
0:23:44	0.065617166	-0.589265585	**0:26:52**	-0.078608587	-0.198605984	**0:30:00**	-0.07713028	0.462489367
0:23:48	0.089973457	-0.592017412	**0:26:56**	-0.079320237	-0.174559459	**0:30:04**	-0.074453831	0.471585363
0:23:52	0.114329748	-0.596220434	**0:27:00**	-0.076981664	-0.151367694	**0:30:08**	-0.076025404	0.48068133
0:30:12	-0.077596977	0.485666573	**0:33:16**	0.091812596	-0.517070711	**0:36:20**	-0.053246714	-0.161057651
0:30:16	-0.085438512	0.490651816	**0:33:20**	0.079821721	-0.507260144	**0:36:24**	-0.048412353	-0.149276271
0:30:20	-0.099550024	0.494611353	**0:33:24**	0.067830846	-0.498144865	**0:36:28**	-0.047922954	-0.137494892
0:30:24	-0.113661528	0.497545123	**0:33:28**	0.075896017	-0.489029586	**0:36:32**	-0.047433559	-0.123905748
0:30:28	-0.114408977	0.500478864	**0:33:32**	0.083961189	-0.478457063	**0:36:36**	-0.052123599	-0.110316597
0:30:32	-0.115156427	0.503412664	**0:33:36**	0.086463369	-0.467884541	**0:36:40**	-0.058540121	-0.098165594
0:30:36	-0.109706759	0.506346464	**0:33:40**	0.083402574	-0.456257492	**0:36:44**	-0.06861791	-0.087452725
0:30:40	-0.09805999	0.509603143	**0:33:44**	0.080341779	-0.443575919	**0:36:48**	-0.089679524	-0.076739855
0:30:44	-0.084508665	0.513182759	**0:33:48**	0.08613871	-0.430894345	**0:36:52**	-0.110741138	-0.100688592
0:30:48	-0.065243691	0.516762376	**0:33:52**	0.091935642	-0.474220216	**0:36:56**	-0.128026932	-0.124637328
0:30:52	-0.045978725	0.534201264	**0:33:56**	0.086932309	-0.517546058	**0:37:00**	-0.144054115	-0.17171818
0:30:56	-0.029558875	0.551640213	**0:34:00**	0.071128711	-0.517939746	**0:37:04**	-0.155874163	-0.241931155
0:31:00	-0.015984148	0.571358442	**0:34:04**	0.055325113	-0.475401163	**0:37:08**	-0.155072793	-0.31214413
0:31:04	-0.002409421	0.593355954	**0:34:08**	0.058039334	-0.43286258	**0:37:12**	-0.154271424	-0.342128754
0:31:08	0.022237675	0.615353525	**0:34:12**	0.060753554	-0.390323997	**0:37:16**	-0.168898404	-0.372113377
0:31:12	0.046884775	0.616210818	**0:34:16**	0.053288579	-0.347785443	**0:37:20**	-0.188668162	-0.387807369
0:31:16	0.074314035	0.617068112	**0:34:20**	0.035644408	-0.310472876	**0:37:24**	-0.19878678	-0.38921079
0:31:20	0.104525469	0.552784145	**0:34:24**	0.018000236	-0.278386354	**0:37:28**	-0.179952025	-0.390614212
0:31:24	0.134736896	0.423358798	**0:34:28**	-0.013064922	-0.246299803	**0:37:32**	-0.161117271	-0.378809839
0:31:28	0.158426896	0.293933451	**0:34:32**	-0.044130079	-0.220900774	**0:37:36**	-0.140420005	-0.367005467
0:31:32	0.182116896	0.12167947	**0:34:36**	-0.070274815	-0.195501745	**0:37:40**	-0.119101897	-0.352215767
0:31:36	0.203654557	-0.050574504	**0:34:40**	-0.09149912	-0.174002111	**0:37:44**	-0.087246038	-0.334440678
0:31:40	0.22303988	-0.189317465	**0:34:44**	-0.112723425	-0.156401873	**0:37:48**	-0.023776937	-0.31666562
0:31:44	0.242425188	-0.294549376	**0:34:48**	-0.115303449	-0.138801634	**0:37:52**	0.039692167	-0.293596536
0:31:48	0.246698171	-0.399781317	**0:34:52**	-0.117883474	-0.128937975	**0:37:56**	0.084627509	-0.270527422
0:31:52	0.250971138	-0.460362047	**0:34:56**	-0.117830165	-0.119074322	**0:38:00**	0.12956284	-0.248222232
0:31:56	0.255244106	-0.520942807	**0:35:00**	-0.115143515	-0.11230389	**0:38:04**	0.173724413	-0.226680934
0:32:00	0.259517103	-0.552845418	**0:35:04**	-0.112718493	-0.108626686	**0:38:08**	0.215564668	-0.205139637
0:32:04	0.263790071	-0.575188696	**0:35:08**	-0.111078352	-0.104949482	**0:38:12**	0.257404923	-0.185198903
0:32:08	0.268063039	-0.597531974	**0:35:12**	-0.109438203	-0.104553059	**0:38:16**	0.26371333	-0.165258184
0:32:12	0.272336006	-0.605149567	**0:35:16**	-0.107798062	-0.104156636	**0:38:20**	0.258177817	-0.146639258
0:32:16	0.270554334	-0.61276716	**0:35:20**	-0.120313048	-0.105229735	**0:38:24**	0.252642304	-0.129342154
0:32:20	0.262717992	-0.619221866	**0:35:24**	-0.132828027	-0.107772373	**0:38:28**	0.247106776	-0.11204505
0:32:24	0.25488165	-0.624513626	**0:35:28**	-0.135563582	-0.110315003	**0:38:32**	0.241571262	-0.099947862

Time	Average Signal	Aggressive Signal	Time	Average Signal	Aggressive Signal	Time	Average Signal	Aggressive Signal
0:32:28	0.234977037	-0.629805386	**0:35:32**	-0.138299152	-0.11593578	**0:38:36**	0.24404037	-0.087850675
0:32:32	0.215072438	-0.626181543	**0:35:36**	-0.135642454	-0.12155655	**0:38:40**	0.249177694	-0.07850796
0:32:36	0.202280566	-0.62255764	**0:35:40**	-0.131188318	-0.128110647	**0:38:44**	0.256531477	-0.071919732
0:32:40	0.19660145	-0.616029859	**0:35:44**	-0.125099853	-0.135598063	**0:38:48**	0.270534575	-0.065331504
0:32:44	0.19092232	-0.606598198	**0:35:48**	-0.114108309	-0.14308548	**0:38:52**	0.284537673	-0.064053401
0:32:48	0.173740223	-0.597166479	**0:35:52**	-0.103116781	-0.151730359	**0:38:56**	0.286429793	-0.062775306
0:32:52	0.156558126	-0.585349619	**0:35:56**	-0.087126561	-0.160375237	**0:39:00**	0.28428486	-0.063185476
0:32:56	0.147368282	-0.57353276	**0:36:00**	-0.069470108	-0.167192742	**0:39:04**	0.286369622	-0.065283924
0:33:00	0.14617072	-0.561715961	**0:36:04**	-0.057029136	-0.172182858	**0:39:08**	0.301143408	-0.067382373
0:33:04	0.140957594	-0.549899101	**0:36:08**	-0.060234591	-0.177172974	**0:39:12**	0.315917194	-0.069480821
0:33:08	0.123697773	-0.538082242	**0:36:12**	-0.063440047	-0.173083127	**0:39:16**	0.322887719	-0.07157927
0:33:12	0.106437944	-0.527576447	**0:36:16**	-0.059529398	-0.168993279	**0:39:20**	0.327257127	-0.074878335
0:39:24	0.323993117	-0.079378024	**0:42:28**	-0.088484794	0.134577245	**0:45:32**	-0.120135874	-0.407382339
0:39:28	0.313095748	-0.083877712	**0:42:32**	-0.07792908	0.120369174	**0:45:36**	-0.126082376	-0.426173925
0:39:32	0.30219835	-0.088377394	**0:42:36**	-0.064050093	0.106161103	**0:45:40**	-0.133827597	-0.440561652
0:39:36	0.285736471	-0.092877083	**0:42:40**	-0.049063344	0.088851109	**0:45:44**	-0.141572818	-0.45054552
0:39:40	0.267419755	-0.098094717	**0:42:44**	-0.032324664	0.068439186	**0:45:48**	-0.140020922	-0.460529387
0:39:44	0.249964669	-0.104030289	**0:42:48**	-0.010330186	0.048027273	**0:45:52**	-0.13846904	-0.470513254
0:39:48	0.233371168	-0.109965868	**0:42:52**	0.011664291	-0.029392079	**0:45:56**	-0.143963248	-0.480497122
0:39:52	0.216777667	-0.139458835	**0:42:56**	0.025807267	-0.106811427	**0:46:00**	-0.156503558	-0.509838402
0:39:56	0.187349871	-0.168951809	**0:43:00**	0.037333075	-0.173284769	**0:46:04**	-0.169043869	-0.558537126
0:40:00	0.153643966	-0.187865153	**0:43:04**	0.049143858	-0.228812099	**0:46:08**	-0.184047908	-0.607235789
0:40:04	0.138993129	-0.196198881	**0:43:08**	0.061809555	-0.284339428	**0:46:12**	-0.199051946	-0.643144369
0:40:08	0.143397331	-0.204532593	**0:43:12**	0.074475259	-0.302268565	**0:46:16**	-0.205388725	-0.679052889
0:40:12	0.147801548	-0.212028667	**0:43:16**	0.088405587	-0.320197672	**0:46:20**	-0.203058258	-0.701789558
0:40:16	0.161009148	-0.219524741	**0:43:20**	0.102757461	-0.329442739	**0:46:24**	-0.200727791	-0.711354375
0:40:20	0.177151233	-0.225644723	**0:43:24**	0.116369769	-0.330003709	**0:46:28**	-0.172829062	-0.720919132
0:40:24	0.178395331	-0.230388641	**0:43:28**	0.127763361	-0.330564708	**0:46:32**	-0.144930333	-0.709490418
0:40:28	0.164741457	-0.235132545	**0:43:32**	0.139156967	-0.321760088	**0:46:36**	-0.115501367	-0.698061705
0:40:32	0.151087582	-0.235192031	**0:43:36**	0.153329521	-0.312955439	**0:46:40**	-0.08454217	-0.681348979
0:40:36	0.123059958	-0.235251516	**0:43:40**	0.168428376	-0.302695423	**0:46:44**	-0.05358297	-0.659352243
0:40:40	0.090241089	-0.230933741	**0:43:44**	0.182257071	-0.290979981	**0:46:48**	-0.018229576	-0.637355506
0:40:44	0.056587346	-0.22223869	**0:43:48**	0.192275256	-0.279264569	**0:46:52**	0.017123818	-0.611929059
0:40:48	0.020428993	-0.213543639	**0:43:52**	0.202293426	-0.271892697	**0:46:56**	0.042132393	-0.586502612
0:40:52	-0.015729358	-0.192310631	**0:43:56**	0.187028632	-0.264520824	**0:47:00**	0.056796148	-0.559995353
0:40:56	-0.042232085	-0.171077624	**0:44:00**	0.171763822	-0.257148981	**0:47:04**	0.071459904	-0.532407165
0:41:00	-0.065516271	-0.145327434	**0:44:04**	0.153605983	-0.249777108	**0:47:08**	0.069582216	-0.504819036
0:41:04	-0.087599136	-0.115060061	**0:44:08**	0.126768962	-0.242405236	**0:47:12**	0.067704529	-0.478195578
0:41:08	-0.106078044	-0.084792681	**0:44:12**	0.099931948	-0.236080617	**0:47:16**	0.068705946	-0.45157212
0:41:12	-0.124556951	-0.052965395	**0:44:16**	0.080253884	-0.229756013	**0:47:20**	0.072586484	-0.428235501
0:41:16	-0.139213055	-0.021138106	**0:44:20**	0.062962145	-0.225157574	**0:47:24**	0.076467015	-0.40818572
0:41:20	-0.152594909	0.008602172	**0:44:24**	0.049071316	-0.2222853	**0:47:28**	0.086649567	-0.38813597
0:41:24	-0.163542613	0.036255442	**0:44:28**	0.045383219	-0.219413042	**0:47:32**	0.096832119	-0.369169712
0:41:28	-0.167187944	0.063908711	**0:44:32**	0.041695122	-0.221587613	**0:47:36**	0.097432934	-0.350203425
0:41:32	-0.170833275	0.086980365	**0:44:36**	0.03219812	-0.223762184	**0:47:40**	0.088452011	-0.327296257
0:41:36	-0.195135266	0.110052019	**0:44:40**	0.020764815	-0.228904158	**0:47:44**	0.079471089	-0.300448179

Time	Average Signal	Aggressive Signal	Time	Average Signal	Aggressive Signal	Time	Average Signal	Aggressive Signal
0:41:40	-0.226322815	0.129442468	**0:44:44**	0.010217833	-0.237013564	**0:47:48**	0.070490167	-0.273600101
0:41:44	-0.247826397	0.145151719	**0:44:48**	0.002329826	-0.245122954	**0:47:52**	0.06150924	-0.238925785
0:41:48	-0.240278065	0.160860971	**0:44:52**	-0.005558181	-0.256909192	**0:47:56**	0.044760838	-0.204251453
0:41:52	-0.232729733	0.168106869	**0:44:56**	-0.023575706	-0.268695474	**0:48:00**	0.02024495	-0.167157039
0:41:56	-0.220912755	0.175352782	**0:45:00**	-0.044969738	-0.272470295	**0:48:04**	-0.004270935	-0.127642542
0:42:00	-0.207672879	0.178375691	**0:45:04**	-0.063236035	-0.268233687	**0:48:08**	-0.007168626	-0.088128045
0:42:04	-0.191694528	0.177175626	**0:45:08**	-0.072119139	-0.263997078	**0:48:12**	-0.010066317	-0.045626983
0:42:08	-0.167500734	0.175975561	**0:45:12**	-0.081002243	-0.28778255	**0:48:16**	-0.015785161	-0.003125921
0:42:12	-0.143306926	0.1696565	**0:45:16**	-0.091497138	-0.311568022	**0:48:20**	-0.02432516	0.039375141
0:42:16	-0.126584753	0.163337439	**0:45:20**	-0.102529287	-0.336486757	**0:48:24**	-0.032865159	0.081876203
0:42:20	-0.112353146	0.155057773	**0:45:24**	-0.111840338	-0.362538785	**0:48:28**	-0.041405156	0.124377266
0:42:24	-0.099040508	0.144817501	**0:45:28**	-0.115988106	-0.388590783	**0:48:32**	-0.049945153	0.163682744
0:48:36	-0.061731566	0.202988237	**0:51:40**	-0.612497032	0.621339917	**0:54:44**	0.208751485	-0.278212279
0:48:40	-0.076764397	0.239145949	**0:51:44**	-0.610040307	0.604619682	**0:54:48**	0.233335853	-0.28887853
0:48:44	-0.091797225	0.272155911	**0:51:48**	-0.601915717	0.587899506	**0:54:52**	0.257920235	-0.339830458
0:48:48	-0.081949078	0.305165857	**0:51:52**	-0.593791068	0.526616395	**0:54:56**	0.276153684	-0.390782386
0:48:52	-0.072100922	0.395747632	**0:51:56**	-0.573378682	0.465333223	**0:55:00**	0.288036197	-0.449650049
0:48:56	-0.069992743	0.486329436	**0:52:00**	-0.540678501	0.370833308	**0:55:04**	0.299918711	-0.516433477
0:49:00	-0.075624533	0.591400802	**0:52:04**	-0.50797832	0.243116587	**0:55:08**	0.317984998	-0.583216846
0:49:04	-0.081256323	0.710961699	**0:52:08**	-0.449476629	0.115399875	**0:55:12**	0.336051285	-0.603971541
0:49:08	-0.103984214	0.830522597	**0:52:12**	-0.390974939	0.030582486	**0:55:16**	0.363847852	-0.624726176
0:49:12	-0.126712099	0.897320628	**0:52:16**	-0.344907075	-0.054234903	**0:55:20**	0.401374668	-0.647768259
0:49:16	-0.134241879	0.964118659	**0:52:20**	-0.30298385	-0.118818089	**0:55:24**	0.438901514	-0.67309773
0:49:20	-0.136705607	0.998014092	**0:52:24**	-0.261060596	-0.163167089	**0:55:28**	0.478370279	-0.6984272
0:49:24	-0.139169335	0.999007046	**0:52:28**	-0.213715687	-0.207516074	**0:55:32**	0.517839015	-0.710735261
0:49:28	-0.139666006	1	**0:52:32**	-0.166370779	-0.227708563	**0:55:36**	0.546050131	-0.723043323
0:49:32	-0.140162677	1	**0:52:36**	-0.131383315	-0.247901052	**0:55:40**	0.570508778	-0.731347024
0:49:36	-0.139673471	1	**0:52:40**	-0.108753294	-0.261604011	**0:55:44**	0.590425313	-0.735646367
0:49:40	-0.138198361	1	**0:52:44**	-0.086123273	-0.268817455	**0:55:48**	0.596715808	-0.739945769
0:49:44	-0.136723265	1	**0:52:48**	-0.059309252	-0.276030898	**0:55:52**	0.603006363	-0.740532875
0:49:48	-0.139861867	1	**0:52:52**	-0.03249523	-0.275200605	**0:55:56**	0.614759088	-0.74112004
0:49:52	-0.143000484	1	**0:52:56**	-0.008562541	-0.274370283	**0:56:00**	0.628332496	-0.741707146
0:49:56	-0.157831013	1	**0:53:00**	0.014409705	-0.271196038	**0:56:04**	0.639077842	-0.742294312
0:50:00	-0.184353486	1	**0:53:04**	0.037381951	-0.265677869	**0:56:08**	0.641338766	-0.742881417
0:50:04	-0.210875943	1	**0:53:08**	0.066252165	-0.260159701	**0:56:12**	0.643599689	-0.746709049
0:50:08	-0.230153844	1	**0:53:12**	0.095122382	-0.25278911	**0:56:16**	0.649659455	-0.75053668
0:50:12	-0.249431744	1	**0:53:16**	0.108717576	-0.245418549	**0:56:20**	0.656985521	-0.754867971
0:50:16	-0.270263523	1	**0:53:20**	0.107037745	-0.239167437	**0:56:24**	0.668605387	-0.759702802
0:50:20	-0.29264918	0.992753565	**0:53:24**	0.105357915	-0.23403582	**0:56:28**	0.69310683	-0.764537632
0:50:24	-0.315034837	0.978260756	**0:53:28**	0.100886099	-0.228904203	**0:56:32**	0.717608273	-0.766188562
0:50:28	-0.321946889	0.963767886	**0:53:32**	0.088038333	-0.227699891	**0:56:36**	0.724306524	-0.767839432
0:50:32	-0.328858942	0.942291021	**0:53:36**	0.080427513	-0.226495564	**0:56:40**	0.725070357	-0.764999926
0:50:36	-0.341190189	0.920814157	**0:53:40**	0.078053631	-0.227309838	**0:56:44**	0.723237038	-0.757670045
0:50:40	-0.358940661	0.898212731	**0:53:44**	0.075679749	-0.230142713	**0:56:48**	0.71361196	-0.750340104
0:50:44	-0.376691133	0.874486744	**0:53:48**	0.060873337	-0.232975587	**0:56:52**	0.703986943	-0.732811868
0:50:48	-0.406778246	0.850760698	**0:53:52**	0.046066925	-0.238161623	**0:56:56**	0.683914781	-0.715283632

Time	Average Signal	Aggressive Signal	Time	Average Signal	Aggressive Signal	Time	Average Signal	Aggressive Signal
0:50:52	-0.436865389	0.827034712	**0:53:56**	0.032489244	-0.24334766	**0:57:00**	0.660360217	-0.69493407
0:50:56	-0.471258134	0.803308725	**0:54:00**	0.020140294	-0.247515023	**0:57:04**	0.630424142	-0.671763062
0:51:00	-0.509956539	0.781970203	**0:54:04**	0.007791343	-0.250663728	**0:57:08**	0.581343651	-0.648592055
0:51:04	-0.548654914	0.763019085	**0:54:08**	0.008938218	-0.253812402	**0:57:12**	0.53226316	-0.627071559
0:51:08	-0.569556415	0.744067967	**0:54:12**	0.010085092	-0.252890021	**0:57:16**	0.481185377	-0.605551124
0:51:12	-0.590457916	0.727725923	**0:54:16**	0.017943749	-0.251967609	**0:57:20**	0.42944178	-0.582796752
0:51:16	-0.600985646	0.711383879	**0:54:20**	0.032514192	-0.251045227	**0:57:24**	0.389031202	-0.558808565
0:51:20	-0.601139605	0.695654571	**0:54:24**	0.047084633	-0.250122815	**0:57:28**	0.359953612	-0.534820318
0:51:24	-0.601293564	0.680538058	**0:54:28**	0.076109484	-0.249200433	**0:57:32**	0.330876023	-0.506171942
0:51:28	-0.607249022	0.665421546	**0:54:32**	0.105134338	-0.254405439	**0:57:36**	0.282100797	-0.477523595
0:51:32	-0.61320442	0.651132941	**0:54:36**	0.138670802	-0.259610444	**0:57:40**	0.226759717	-0.447463244
0:51:36	-0.614953756	0.636844337	**0:54:40**	0.173711151	-0.267546058	**0:57:44**	0.176583067	-0.415990949
0:57:48	0.141899735	-0.384518623	**1:00:52**	-0.574509323	0.063227363	**1:03:56**	-0.011699418	-0.1217774
0:57:52	0.10721641	-0.273000509	**1:00:56**	-0.553252459	0.085266471	**1:04:00**	-0.035099406	-0.142075285
0:57:56	0.081901066	-0.161482364	**1:01:00**	-0.532218754	0.101926014	**1:04:04**	-0.062148694	-0.1519171
0:58:00	0.056585718	-0.081884257	**1:01:04**	-0.516960323	0.113205977	**1:04:08**	-0.100145899	-0.1617589
0:58:04	0.030142466	-0.034206167	**1:01:08**	-0.519027829	0.12448594	**1:04:12**	-0.138143107	-0.138165668
0:58:08	0.000315489	0.013471927	**1:01:12**	-0.521095395	0.122961879	**1:04:16**	-0.159220174	-0.114572428
0:58:12	-0.029511487	0.01790119	**1:01:16**	-0.524023652	0.121437818	**1:04:20**	-0.174657211	-0.092906609
0:58:16	-0.05869814	0.022330452	**1:01:20**	-0.527238786	0.118761301	**1:04:24**	-0.18650648	-0.073168203
0:58:20	-0.087671354	0.029769493	**1:01:24**	-0.527811944	0.114932336	**1:04:28**	-0.187592462	-0.053429801
0:58:24	-0.113062873	0.040218312	**1:01:28**	-0.520459056	0.111103363	**1:04:32**	-0.188678443	-0.033691395
0:58:28	-0.127709314	0.050667133	**1:01:32**	-0.513106167	0.114228234	**1:04:36**	-0.164316848	-0.01395299
0:58:32	-0.142355755	0.069809258	**1:01:36**	-0.492948204	0.117353097	**1:04:40**	-0.131472722	0.009232687
0:58:36	-0.166236892	0.088951387	**1:01:40**	-0.468521863	0.120477967	**1:04:44**	-0.097253986	0.035865635
0:58:40	-0.193196267	0.109362289	**1:01:44**	-0.442765445	0.12360283	**1:04:48**	-0.058911398	0.062498584
0:58:44	-0.225753248	0.131041989	**1:01:48**	-0.413018793	0.1267277	**1:04:52**	-0.020568807	0.07013119
0:58:48	-0.275103092	0.152721673	**1:01:52**	-0.383272141	0.123250894	**1:04:56**	0.017095545	0.077763796
0:58:52	-0.324452937	0.174401373	**1:01:56**	-0.362186193	0.119774088	**1:05:00**	0.054533817	0.091889605
0:58:56	-0.354490727	0.196081057	**1:02:00**	-0.343987167	0.115371756	**1:05:04**	0.08557938	0.112508602
0:59:00	-0.378091216	0.216172591	**1:02:04**	-0.323312312	0.110043891	**1:05:08**	0.097446807	0.1331276
0:59:04	-0.39722997	0.234675974	**1:02:08**	-0.295210004	0.104716025	**1:05:12**	0.109314233	0.158699572
0:59:08	-0.402983665	0.253179342	**1:02:12**	-0.267107695	0.101111971	**1:05:16**	0.110737503	0.184271559
0:59:12	-0.408737361	0.253736436	**1:02:16**	-0.228181422	0.097507924	**1:05:20**	0.108679391	0.207279548
0:59:16	-0.411205947	0.254293531	**1:02:20**	-0.185647145	0.08806245	**1:05:24**	0.105224237	0.227723539
0:59:20	-0.412579447	0.250716746	**1:02:24**	-0.146814808	0.07277555	**1:05:28**	0.097577974	0.24816753
0:59:24	-0.419098258	0.243006095	**1:02:28**	-0.119088247	0.05748865	**1:05:32**	0.089931704	0.264663935
0:59:28	-0.441052914	0.235295445	**1:02:32**	-0.091361687	0.055736918	**1:05:36**	0.073569283	0.281160325
0:59:32	-0.463007569	0.227584794	**1:02:36**	-0.063635133	0.053985186	**1:05:40**	0.048490699	0.295966357
0:59:36	-0.479398698	0.219874144	**1:02:40**	-0.035908572	0.052233454	**1:05:44**	0.023412118	0.309082031
0:59:40	-0.493935287	0.212163493	**1:02:44**	-0.010398516	0.050481722	**1:05:48**	0.0095454	0.322197706
0:59:44	-0.508034348	0.204452842	**1:02:48**	0.00846204	0.04872999	**1:05:52**	-0.004321319	0.333109826
0:59:48	-0.520820737	0.197237194	**1:02:52**	0.027322596	0.04021379	**1:05:56**	-0.002285655	0.344021976
0:59:52	-0.533607125	0.19150658	**1:02:56**	0.03439831	0.03169759	**1:06:00**	0.01565239	0.353272468
0:59:56	-0.571674705	0.185775965	**1:03:00**	0.037545741	0.023997007	**1:06:04**	0.033590436	0.360861361
1:00:00	-0.618169308	0.174373448	**1:03:04**	0.043551557	0.017112037	**1:06:08**	0.100381702	0.368450254

Time	Average Signal	Aggressive Signal	Time	Average Signal	Aggressive Signal	Time	Average Signal	Aggressive Signal
1:00:04	-0.656856894	0.157299012	**1:03:08**	0.058132537	0.010227067	**1:06:12**	0.167172968	0.380681723
1:00:08	-0.672123194	0.140224606	**1:03:12**	0.072713517	0.004234673	**1:06:16**	0.231837362	0.392913222
1:00:12	-0.687389493	0.123150177	**1:03:16**	0.058027036	-0.001757722	**1:06:20**	0.294374853	0.406614751
1:00:16	-0.698618889	0.106075756	**1:03:20**	0.033584733	-0.006581043	**1:06:24**	0.356912374	0.421786368
1:00:20	-0.70850265	0.090442404	**1:03:24**	0.009142428	-0.01023529	**1:06:28**	0.382028908	0.436957955
1:00:24	-0.713597298	0.076250128	**1:03:28**	-0.006991531	-0.013889536	**1:06:32**	0.407145441	0.452129573
1:00:28	-0.704324484	0.062057849	**1:03:32**	-0.014817143	-0.020872151	**1:06:36**	0.436691225	0.46730119
1:00:32	-0.69505167	0.055418726	**1:03:36**	-0.013008	-0.027854767	**1:06:40**	0.4706662	0.482806802
1:00:36	-0.672066331	0.048779603	**1:03:40**	-0.007987272	-0.037130751	**1:06:44**	0.504641175	0.498646438
1:00:40	-0.64451009	0.044605684	**1:03:44**	-0.003214495	-0.048700098	**1:06:48**	0.515115559	0.514486074
1:00:44	-0.618361413	0.042896971	**1:03:48**	0.000814423	-0.060269449	**1:06:52**	0.525589943	0.454237819
1:00:48	-0.596435368	0.041188255	**1:03:52**	0.004843342	-0.091023423	**1:06:56**	0.540131867	0.393989593
1:07:00	0.558741331	0.356477559	**1:10:04**	-0.442958772	0.029606774	**1:13:08**	-0.066804774	-0.269807339
1:07:04	0.577350855	0.341701776	**1:10:08**	-0.446461916	-0.000784331	**1:13:12**	-0.062666923	-0.263669968
1:07:08	0.5741359	0.326925963	**1:10:12**	-0.44996509	-0.019187972	**1:13:16**	-0.054492291	-0.257532567
1:07:12	0.570920885	0.327572823	**1:10:16**	-0.447122872	-0.025604144	**1:13:20**	-0.042280883	-0.247634545
1:07:16	0.570378959	0.328219682	**1:10:20**	-0.437935323	-0.027446218	**1:13:24**	-0.030069474	-0.233975887
1:07:20	0.572510064	0.331011295	**1:10:24**	-0.428747773	-0.024714191	**1:13:28**	-0.017858066	-0.22031723
1:07:24	0.574641168	0.335947663	**1:10:28**	-0.425177574	-0.021982163	**1:13:32**	0.007479372	-0.201210186
1:07:28	0.574459732	0.34088406	**1:10:32**	-0.421607345	-0.012934535	**1:13:36**	0.030449376	-0.182103142
1:07:32	0.574278235	0.343459427	**1:10:36**	-0.425561041	-0.003886906	**1:13:40**	0.046317082	-0.163949832
1:07:36	0.56793797	0.346034795	**1:10:40**	-0.4370386	0.005160722	**1:13:44**	0.062184788	-0.146750271
1:07:40	0.555438817	0.347102791	**1:10:44**	-0.44851616	0.014208351	**1:13:48**	0.082672328	-0.129550695
1:07:44	0.542939663	0.346663356	**1:10:48**	-0.441635221	0.02325598	**1:13:52**	0.103159867	-0.11778035
1:07:48	0.533623219	0.34622395	**1:10:52**	-0.434754282	0.030226758	**1:13:56**	0.123180613	-0.106010005
1:07:52	0.524306834	0.345784515	**1:10:56**	-0.429251164	0.037197534	**1:14:00**	0.142734572	-0.097724773
1:07:56	0.513461888	0.34534511	**1:11:00**	-0.425125867	0.043009408	**1:14:04**	0.162288517	-0.092924662
1:08:00	0.50108844	0.344905674	**1:11:04**	-0.42100057	0.047662377	**1:14:08**	0.175971583	-0.088124551
1:08:04	0.488714963	0.344466269	**1:11:08**	-0.400860399	0.052315347	**1:14:12**	0.189654648	-0.089633055
1:08:08	0.465323329	0.344026834	**1:11:12**	-0.380720228	0.052240014	**1:14:16**	0.211057723	-0.091141567
1:08:12	0.441931695	0.342830986	**1:11:16**	-0.364572853	0.052164681	**1:14:20**	0.240180805	-0.095574327
1:08:16	0.417364597	0.341635138	**1:11:20**	-0.352418274	0.049086925	**1:14:24**	0.269303888	-0.102931343
1:08:20	0.392405689	0.338976026	**1:11:24**	-0.341873199	0.043006744	**1:14:28**	0.289850503	-0.110288359
1:08:24	0.36744675	0.334853679	**1:11:28**	-0.336156577	0.036926564	**1:14:32**	0.310397118	-0.124826275
1:08:28	0.329547077	0.330731332	**1:11:32**	-0.330439985	0.026021881	**1:14:36**	0.32410726	-0.139364183
1:08:32	0.291647404	0.322955489	**1:11:36**	-0.316324443	0.0151172	**1:14:40**	0.330980957	-0.157261983
1:08:36	0.253118426	0.315179616	**1:11:40**	-0.29380995	0.004212518	**1:14:44**	0.337854624	-0.178519636
1:08:40	0.213960126	0.306598485	**1:11:44**	-0.271295488	-0.006692165	**1:14:48**	0.340599895	-0.199777305
1:08:44	0.174801841	0.297212124	**1:11:48**	-0.252616912	-0.017596846	**1:14:52**	0.343345195	-0.221034974
1:08:48	0.114809677	0.287825704	**1:11:52**	-0.233938336	-0.023324598	**1:14:56**	0.344330668	-0.242292628
1:08:52	0.054817509	0.278439343	**1:11:56**	-0.210659534	-0.029052349	**1:15:00**	0.343556374	-0.262176931
1:08:56	-0.006586801	0.269052923	**1:12:00**	-0.182780489	-0.03146036	**1:15:04**	0.34278208	-0.280687839
1:09:00	-0.068461828	0.260228902	**1:12:04**	-0.154901445	-0.030548636	**1:15:08**	0.35939908	-0.299198776
1:09:04	-0.130336851	0.251967251	**1:12:08**	-0.159801349	-0.029636912	**1:15:12**	0.376016051	-0.31909132
1:09:08	-0.176112041	0.243705571	**1:12:12**	-0.164701253	-0.023456587	**1:15:16**	0.392633051	-0.338983864
1:09:12	-0.221887231	0.238561928	**1:12:16**	-0.168622106	-0.017276259	**1:15:20**	0.409250021	-0.358876437

Time	Average Signal	Aggressive Signal	Time	Average Signal	Aggressive Signal	Time	Average Signal	Aggressive Signal
1:09:16	-0.267150372	0.233418286	**1:12:20**	-0.171563908	-0.009999882	**1:15:24**	0.425867021	-0.378768981
1:09:20	-0.31190148	0.234872162	**1:12:24**	-0.174505726	-0.001627456	**1:15:28**	0.418198347	-0.398661524
1:09:24	-0.356652588	0.242923573	**1:12:28**	-0.168541655	0.006744971	**1:15:32**	0.410529703	-0.406015545
1:09:28	-0.395771027	0.250974983	**1:12:32**	-0.162577584	0.013546283	**1:15:36**	0.398420632	-0.413369536
1:09:32	-0.434889466	0.255565941	**1:12:36**	-0.161243364	0.020347595	**1:15:40**	0.381871134	-0.41971609
1:09:36	-0.457653761	0.2601569	**1:12:40**	-0.16453898	0.026047152	**1:15:44**	0.365321636	-0.425055176
1:09:40	-0.464063853	0.261259228	**1:12:44**	-0.167834595	0.030644953	**1:15:48**	0.330869257	-0.430394262
1:09:44	-0.470473945	0.258872926	**1:12:48**	-0.158429995	0.035242755	**1:15:52**	0.296416849	-0.484576195
1:09:48	-0.452385038	0.256486624	**1:12:52**	-0.149025381	-0.055772848	**1:15:56**	0.28083232	-0.538758159
1:09:52	-0.434296131	0.183969349	**1:12:56**	-0.129646987	-0.146788448	**1:16:00**	0.284115613	-0.579498172
1:09:56	-0.428793103	0.111452073	**1:13:00**	-0.100294814	-0.207798466	**1:16:04**	0.287398934	-0.606796265
1:10:00	-0.435875952	0.059997883	**1:13:04**	-0.070942633	-0.23880291	**1:16:08**	0.272401512	-0.634094357
1:16:12	0.257404089	-0.635279655	**1:19:16**	-0.305900812	-0.098767042	**1:22:20**	0.016346565	1
1:16:16	0.236102685	-0.636464953	**1:19:20**	-0.318654776	-0.076010831	**1:22:24**	0.037200753	1
1:16:20	0.208497256	-0.635039926	**1:19:24**	-0.331408739	-0.063652858	**1:22:28**	0.038560804	1
1:16:24	0.180891827	-0.631004512	**1:19:28**	-0.349278867	-0.051294886	**1:22:32**	0.039920855	1
1:16:28	0.149290666	-0.626969099	**1:19:32**	-0.367148966	-0.049098067	**1:22:36**	0.044619635	1
1:16:32	0.117689505	-0.622933745	**1:19:36**	-0.367434502	-0.046901245	**1:22:40**	0.052657142	1
1:16:36	0.104235724	-0.618898332	**1:19:40**	-0.350135416	-0.04776426	**1:22:44**	0.06069465	1
1:16:40	0.096831061	-0.615439713	**1:19:44**	-0.33283633	-0.051687106	**1:22:48**	0.06201566	1
1:16:44	0.089426406	-0.612557888	**1:19:48**	-0.326143861	-0.055609953	**1:22:52**	0.06333667	1
1:16:48	0.072851948	-0.609676063	**1:19:52**	-0.319451392	-0.058509286	**1:22:56**	0.05915194	1
1:16:52	0.056277491	-0.606794238	**1:19:56**	-0.323466092	-0.061408624	**1:23:00**	0.049461458	0.989537239
1:16:56	0.041294258	-0.603912413	**1:20:00**	-0.331049889	-0.06327083	**1:23:04**	0.039770976	0.968611658
1:17:00	0.027902246	-0.600537896	**1:20:04**	-0.338633657	-0.064095907	**1:23:08**	0.030080495	0.947686076
1:17:04	0.014510236	-0.596670806	**1:20:08**	-0.347423792	-0.064920984	**1:23:12**	0.020390015	0.926760495
1:17:08	-0.009168825	-0.592803657	**1:20:12**	-0.356213957	-0.060995203	**1:23:16**	0.012533192	0.905834913
1:17:12	-0.032847885	-0.591019571	**1:20:16**	-0.355250478	-0.057069421	**1:23:20**	0.006510028	0.886403143
1:17:16	-0.066966303	-0.589235485	**1:20:20**	-0.344533354	-0.049777631	**1:23:24**	0.000486864	0.868465066
1:17:20	-0.111524083	-0.588962317	**1:20:24**	-0.33381623	-0.039119836	**1:23:28**	-0.0055363	0.850526989
1:17:24	-0.156081855	-0.590200007	**1:20:28**	-0.324084312	-0.028462043	**1:23:32**	-0.028666645	0.831218302
1:17:28	-0.177820206	-0.591437697	**1:20:32**	-0.314352393	-0.012842255	**1:23:36**	-0.055754304	0.811909616
1:17:32	-0.199558541	-0.596644521	**1:20:36**	-0.296291947	0.002777534	**1:23:40**	-0.094713904	0.791350305
1:17:36	-0.21505037	-0.601851404	**1:20:40**	-0.269902945	0.020036351	**1:23:44**	-0.133673504	0.769540429
1:17:40	-0.224295676	-0.610648692	**1:20:44**	-0.243513957	0.038934197	**1:23:48**	-0.156398565	0.747730553
1:17:44	-0.234849602	-0.623036504	**1:20:48**	-0.229813486	0.057832044	**1:23:52**	-0.179123625	0.722923696
1:17:48	-0.249329448	-0.635424256	**1:20:52**	-0.216113016	0.081885174	**1:23:56**	-0.204645038	0.698116839
1:17:52	-0.263809294	-0.648912668	**1:20:56**	-0.199881166	0.105938315	**1:24:00**	-0.232962817	0.67130518
1:17:56	-0.285851181	-0.66240114	**1:21:00**	-0.181117937	0.131448135	**1:24:04**	-0.261280596	0.642488778
1:18:00	-0.310413718	-0.673197448	**1:21:04**	-0.162354693	0.158414662	**1:24:08**	-0.287132919	0.613672316
1:18:04	-0.334976256	-0.681301713	**1:21:08**	-0.16142045	0.185381174	**1:24:12**	-0.312985212	0.579505682
1:18:08	-0.354332596	-0.689405918	**1:21:12**	-0.160486221	0.212347701	**1:24:16**	-0.326897591	0.545339048
1:18:12	-0.373688936	-0.689811409	**1:21:16**	-0.153893963	0.239314228	**1:24:20**	-0.328869998	0.509354651
1:18:16	-0.383343071	-0.690216899	**1:21:20**	-0.141643688	0.265549958	**1:24:24**	-0.330842406	0.471552551
1:18:20	-0.383295	-0.687271535	**1:21:24**	-0.129393414	0.291054934	**1:24:28**	-0.344168156	0.433750451
1:18:24	-0.383246958	-0.680975318	**1:21:28**	-0.12526086	0.316559881	**1:24:32**	-0.357493877	0.39594835

Time	Average Signal	Aggressive Signal	Time	Average Signal	Aggressive Signal	Time	Average Signal	Aggressive Signal
1:18:28	-0.371765047	-0.674679101	**1:21:32**	-0.121128321	0.338306606	**1:24:36**	-0.368293077	0.35814625
1:18:32	-0.360283136	-0.662513196	**1:21:36**	-0.123125069	0.360053331	**1:24:40**	-0.376565695	0.319968998
1:18:36	-0.349548459	-0.650347292	**1:21:40**	-0.131251127	0.380413502	**1:24:44**	-0.384838343	0.281416535
1:18:40	-0.339561075	-0.638181448	**1:21:44**	-0.139377177	0.399387181	**1:24:48**	-0.397633791	0.242864117
1:18:44	-0.329573691	-0.626015544	**1:21:48**	-0.131966338	0.418360829	**1:24:52**	-0.410429269	0.244785532
1:18:48	-0.322824806	-0.61384964	**1:21:52**	-0.124555498	0.492522448	**1:24:56**	-0.427841157	0.246706933
1:18:52	-0.316075921	-0.508200645	**1:21:56**	-0.112740546	0.566684067	**1:25:00**	-0.449869514	0.250845134
1:18:56	-0.309327036	-0.402551591	**1:22:00**	-0.096521489	0.657100916	**1:25:04**	-0.47189784	0.257200092
1:19:00	-0.302578151	-0.312796861	**1:22:04**	-0.080302432	0.763772964	**1:25:08**	-0.490746319	0.26355508
1:19:04	-0.297698975	-0.23893638	**1:22:08**	-0.054155346	0.870445013	**1:25:12**	-0.509594798	0.273133785
1:19:08	-0.298428923	-0.165075913	**1:22:12**	-0.02800826	0.92226702	**1:25:16**	-0.527195156	0.28271246
1:19:12	-0.299158871	-0.13192147	**1:22:16**	-0.004507622	0.974089026	**1:25:20**	-0.543547511	0.28495115
1:25:24	-0.559899807	0.279849857	**1:28:28**	-0.123445265	-0.876365781	**1:31:32**	0.117728151	0.080814742
1:25:28	-0.582634449	0.274748534	**1:28:32**	-0.104168788	-0.88152504	**1:31:36**	0.133420661	0.088202238
1:25:32	-0.605369091	0.261630535	**1:28:36**	-0.087396994	-0.886684299	**1:31:40**	0.146892399	0.090438083
1:25:36	-0.623647094	0.248512566	**1:28:40**	-0.073129885	-0.882432878	**1:31:44**	0.160364121	0.087522276
1:25:40	-0.637468457	0.234280944	**1:28:44**	-0.058862776	-0.868770778	**1:31:48**	0.173835844	0.084606476
1:25:44	-0.651289821	0.218935698	**1:28:48**	-0.061269343	-0.855108678	**1:31:52**	0.187307581	0.094046861
1:25:48	-0.658788383	0.203590453	**1:28:52**	-0.06367591	-0.829212844	**1:31:56**	0.204759836	0.103487238
1:25:52	-0.666286945	0.188245207	**1:28:56**	-0.065522179	-0.80331701	**1:32:00**	0.226192608	0.112927623
1:25:56	-0.679855883	0.172899961	**1:29:00**	-0.066808142	-0.775414944	**1:32:04**	0.247625381	0.122368
1:26:00	-0.699495196	0.15909797	**1:29:04**	-0.068094105	-0.745506644	**1:32:08**	0.266429663	0.131808385
1:26:04	-0.71913451	0.146839246	**1:29:08**	-0.075491987	-0.715598345	**1:32:12**	0.285233945	0.142487884
1:26:08	-0.731681705	0.134580523	**1:29:12**	-0.08288987	-0.691401303	**1:32:16**	0.299840361	0.153167382
1:26:12	-0.744228899	0.128077656	**1:29:16**	-0.090730377	-0.667204261	**1:32:20**	0.310248911	0.158476353
1:26:16	-0.750498056	0.121574774	**1:29:20**	-0.099013507	-0.645814717	**1:32:24**	0.320657462	0.158414796
1:26:20	-0.750489235	0.11704801	**1:29:24**	-0.107296638	-0.62723279	**1:32:28**	0.334339231	0.158353254
1:26:24	-0.750480413	0.114497356	**1:29:28**	-0.089358874	-0.608650863	**1:32:32**	0.34802103	0.160650373
1:26:28	-0.739156902	0.111946695	**1:29:32**	-0.071421109	-0.590068936	**1:32:36**	0.365018964	0.162947491
1:26:32	-0.72783339	0.109396033	**1:29:36**	-0.049309317	-0.57148701	**1:32:40**	0.385333061	0.167692885
1:26:36	-0.709869266	0.106845379	**1:29:40**	-0.023023494	-0.551136672	**1:32:44**	0.405647159	0.174886525
1:26:40	-0.685264587	0.100922629	**1:29:44**	0.003262329	-0.529017985	**1:32:48**	0.421588898	0.182080179
1:26:44	-0.660659909	0.091627799	**1:29:48**	0.016531654	-0.506899297	**1:32:52**	0.437530607	0.189273819
1:26:48	-0.649498105	0.082332961	**1:29:52**	0.029800979	-0.482416481	**1:32:56**	0.450583428	0.196467459
1:26:52	-0.63833636	0.065356314	**1:29:56**	0.036496934	-0.457933664	**1:33:00**	0.460747331	0.201561391
1:26:56	-0.616645694	0.048379671	**1:30:00**	0.036619522	-0.434910297	**1:33:04**	0.470911235	0.204555616
1:27:00	-0.584426165	0.028627425	**1:30:04**	0.036742106	-0.41334641	**1:33:08**	0.470390499	0.207549825
1:27:04	-0.552206635	0.006099584	**1:30:08**	0.031933803	-0.391782522	**1:33:12**	0.469869763	0.206007943
1:27:08	-0.515410423	-0.016428258	**1:30:12**	0.027125502	-0.374998093	**1:33:16**	0.463170946	0.20446606
1:27:12	-0.478614211	-0.041191604	**1:30:16**	0.038487431	-0.358213663	**1:33:20**	0.454412729	0.202924177
1:27:16	-0.445225507	-0.065954953	**1:30:20**	0.066019595	-0.342347383	**1:33:24**	0.445654541	0.201382294
1:27:20	-0.415244281	-0.089501671	**1:30:24**	0.093551755	-0.327399284	**1:33:28**	0.423277527	0.199840412
1:27:24	-0.385263056	-0.111831754	**1:30:28**	0.129236147	-0.312451184	**1:33:32**	0.400900483	0.196244061
1:27:28	-0.378988087	-0.134161845	**1:30:32**	0.164920539	-0.298521578	**1:33:36**	0.385716081	0.19264771
1:27:32	-0.372713119	-0.153074548	**1:30:36**	0.191351101	-0.284592003	**1:33:40**	0.392109543	0.18905136
1:27:36	-0.371592909	-0.171987265	**1:30:40**	0.208527863	-0.271248877	**1:33:44**	0.398503006	0.185455009

Time	Average Signal	Aggressive Signal	Time	Average Signal	Aggressive Signal	Time	Average Signal	Aggressive Signal
1:27:40	-0.375627458	-0.189775497	**1:30:44**	0.22570461	-0.258492202	**1:33:48**	0.423699409	0.181858659
1:27:44	-0.379662037	-0.206439242	**1:30:48**	0.225097165	-0.245735556	**1:33:52**	0.448895812	0.206551865
1:27:48	-0.363772482	-0.223102987	**1:30:52**	0.224489719	-0.201657012	**1:33:56**	0.460877329	0.231245071
1:27:52	-0.347882926	-0.30700478	**1:30:56**	0.219024688	-0.157578468	**1:34:00**	0.45964396	0.278782904
1:27:56	-0.327741653	-0.390906572	**1:31:00**	0.208702043	-0.118506692	**1:34:04**	0.458410591	0.34916532
1:28:00	-0.30334872	-0.483847857	**1:31:04**	0.198379397	-0.084441669	**1:34:08**	0.447501838	0.419547737
1:28:04	-0.278955787	-0.585828543	**1:31:08**	0.171044141	-0.05037665	**1:34:12**	0.436593086	0.465321064
1:28:08	-0.250736207	-0.687809289	**1:31:12**	0.1437089	-0.022386443	**1:34:16**	0.423254639	0.511094391
1:28:12	-0.222516626	-0.730515122	**1:31:16**	0.120413326	0.005603763	**1:34:20**	0.407486469	0.543321192
1:28:16	-0.195085466	-0.773220956	**1:31:20**	0.101157442	0.030364543	**1:34:24**	0.391718298	0.562001348
1:28:20	-0.167917132	-0.810932219	**1:31:24**	0.08190155	0.051895898	**1:34:28**	0.40530929	0.580681562
1:28:24	-0.142721742	-0.84364903	**1:31:28**	0.099814847	0.073427252	**1:34:32**	0.418900251	0.579436541
1:34:36	0.431510657	0.578191519	**1:37:40**	0.844131768	-0.468019247	**1:40:44**	0.084842391	-0.096607029
1:34:40	0.443140477	0.569676578	**1:37:44**	0.849631667	-0.470740587	**1:40:48**	0.038602907	-0.084854566
1:34:44	0.454770297	0.553891778	**1:37:48**	0.824965835	-0.473461896	**1:40:52**	-0.007636577	-0.073102102
1:34:48	0.452098221	0.538106918	**1:37:52**	0.800299942	-0.469753772	**1:40:56**	-0.047738642	-0.061349634
1:34:52	0.449426115	0.516598701	**1:37:56**	0.779529393	-0.466045618	**1:41:00**	-0.08170329	-0.048189286
1:34:56	0.439906329	0.495090425	**1:38:00**	0.762654066	-0.459516138	**1:41:04**	-0.115667932	-0.033621058
1:35:00	0.423538864	0.472049743	**1:38:04**	0.745778799	-0.450165331	**1:41:08**	-0.136460364	-0.019052828
1:35:04	0.407171398	0.447476625	**1:38:08**	0.728903472	-0.440814495	**1:41:12**	-0.157252803	0.000904706
1:35:08	0.405181289	0.422903508	**1:38:12**	0.712028146	-0.431463659	**1:41:16**	-0.183246166	0.020862238
1:35:12	0.403191179	0.396229893	**1:38:16**	0.695990145	-0.422112852	**1:41:20**	-0.21444048	0.037015591
1:35:16	0.413738877	0.369556278	**1:38:20**	0.680789411	-0.413391858	**1:41:24**	-0.245634779	0.049364764
1:35:20	0.436824352	0.342882663	**1:38:24**	0.665588617	-0.405300736	**1:41:28**	-0.274496734	0.061713938
1:35:24	0.459909827	0.316209048	**1:38:28**	0.650387883	-0.397209585	**1:41:32**	-0.303358674	0.066209048
1:35:28	0.484290004	0.289535433	**1:38:32**	0.635187149	-0.392726511	**1:41:36**	-0.341748625	0.070704155
1:35:32	0.508670151	0.263909072	**1:38:36**	0.628696561	-0.388243437	**1:41:40**	-0.389666557	0.084585115
1:35:36	0.527629733	0.23828271	**1:38:40**	0.625109375	-0.383110464	**1:41:44**	-0.426380277	0.107851923
1:35:40	0.5447824	0.215386763	**1:38:44**	0.621522188	-0.377327532	**1:41:48**	-0.429481357	0.13111873
1:35:44	0.561935067	0.195221245	**1:38:48**	0.609051466	-0.371544629	**1:41:52**	-0.432582438	0.150884524
1:35:48	0.572072148	0.175055727	**1:38:52**	0.596580684	-0.364049166	**1:41:56**	-0.449205697	0.170650318
1:35:52	0.582209229	0.160627455	**1:38:56**	0.594513834	-0.356553704	**1:42:00**	-0.479351103	0.188537255
1:35:56	0.587177753	0.146199182	**1:39:00**	0.602850795	-0.348375291	**1:42:04**	-0.50949651	0.204545319
1:36:00	0.586977661	0.133609653	**1:39:04**	0.611187816	-0.339513898	**1:42:08**	-0.531883538	0.220553398
1:36:04	0.586777568	0.122858867	**1:39:08**	0.627466023	-0.330652505	**1:42:12**	-0.554270506	0.231387913
1:36:08	0.601276815	0.112108082	**1:39:12**	0.64374423	-0.318825573	**1:42:16**	-0.579113185	0.242222413
1:36:12	0.615776062	0.102431454	**1:39:16**	0.646987855	-0.30699861	**1:42:20**	-0.606411517	0.250771046
1:36:16	0.621433198	0.092754818	**1:39:20**	0.637196898	-0.295171678	**1:42:24**	-0.633709848	0.257033795
1:36:20	0.618248224	0.083078191	**1:39:24**	0.624941587	-0.283344716	**1:42:28**	-0.649273098	0.263296545
1:36:24	0.61506325	0.073401555	**1:39:28**	0.605293095	-0.271517783	**1:42:32**	-0.664836347	0.269559294
1:36:28	0.622388959	0.063724928	**1:39:32**	0.585644603	-0.262546271	**1:42:36**	-0.680399597	0.275822043
1:36:32	0.629714668	0.052588217	**1:39:36**	0.564082921	-0.253574759	**1:42:40**	-0.695962846	0.281170666
1:36:36	0.633552015	0.04145151	**1:39:40**	0.540608168	-0.244603261	**1:42:44**	-0.711526096	0.285605222
1:36:40	0.633901	0.029734179	**1:39:44**	0.517133415	-0.235631764	**1:42:48**	-0.724182904	0.290039778
1:36:44	0.639066994	0.017436231	**1:39:48**	0.502045751	-0.226660252	**1:42:52**	-0.736839652	0.431818306
1:36:48	0.658684075	0.00513828	**1:39:52**	0.486958027	-0.166231483	**1:42:56**	-0.735217273	0.573596835

Time	Average Signal	Aggressive Signal	Time	Average Signal	Aggressive Signal	Time	Average Signal	Aggressive Signal
1:36:52	0.678301156	-0.04734293	**1:39:56**	0.467710704	-0.105802715	**1:43:00**	-0.719315648	0.709925294
1:36:56	0.697918236	-0.099824145	**1:40:00**	0.444303691	-0.074989848	**1:43:04**	-0.703414083	0.840803564
1:37:00	0.717535317	-0.167980939	**1:40:04**	0.420896709	-0.07379289	**1:43:08**	-0.670739114	0.971681893
1:37:04	0.737152398	-0.251813322	**1:40:08**	0.385578483	-0.072595932	**1:43:12**	-0.638064146	0.98300916
1:37:08	0.759451389	-0.335645705	**1:40:12**	0.350260258	-0.090675972	**1:43:16**	-0.60993588	0.994336367
1:37:12	0.781750381	-0.387345761	**1:40:16**	0.312329561	-0.108756006	**1:43:20**	-0.586354434	1
1:37:16	0.793706715	-0.439045787	**1:40:20**	0.271786392	-0.119915232	**1:43:24**	-0.56277293	1
1:37:20	0.795320511	-0.461463094	**1:40:24**	0.231243193	-0.124153651	**1:43:28**	-0.535267293	1
1:37:24	0.796934307	-0.454597652	**1:40:28**	0.200648129	-0.128392071	**1:43:32**	-0.507761657	1
1:37:28	0.812513351	-0.44773221	**1:40:32**	0.17005305	-0.122729532	**1:43:36**	-0.487634778	1
1:37:32	0.828092396	-0.455302775	**1:40:36**	0.140772894	-0.117066994	**1:43:40**	-0.4896442	1
1:37:36	0.838631868	-0.46287331	**1:40:40**	0.112807639	-0.108359493	**1:43:44**	-0.491653621	1
1:43:48	-0.490011275	1	**1:46:52**	0.357419103	-1	**1:49:56**	0.373788446	1
1:43:52	-0.488368958	1	**1:46:56**	0.374807805	-1	**1:50:00**	0.339713752	0.987224221
1:43:56	-0.488991648	1	**1:47:00**	0.371463418	-1	**1:50:04**	0.305639058	0.961672604
1:44:00	-0.491879404	0.980865538	**1:47:04**	0.368119061	-1	**1:50:08**	0.273789525	0.936121047
1:44:04	-0.49352026	0.942596555	**1:47:08**	0.368144929	-1	**1:50:12**	0.241940007	0.90241003
1:44:08	-0.491420507	0.904327571	**1:47:12**	0.368170798	-1	**1:50:16**	0.224351153	0.868699014
1:44:12	-0.489320755	0.860717535	**1:47:16**	0.364930362	-1	**1:50:20**	0.221022964	0.837182462
1:44:16	-0.491745889	0.817107499	**1:47:20**	0.358423591	-1	**1:50:24**	0.217694789	0.807860434
1:44:20	-0.49869591	0.773497522	**1:47:24**	0.35191685	-1	**1:50:28**	0.205658019	0.778538406
1:44:24	-0.505645931	0.729887486	**1:47:28**	0.357450157	-1	**1:50:32**	0.193621263	0.75060463
1:44:28	-0.502879739	0.686277449	**1:47:32**	0.362983465	-1	**1:50:36**	0.184663832	0.722670853
1:44:32	-0.500113547	0.645007789	**1:47:36**	0.384386331	-1	**1:50:40**	0.178785756	0.69439137
1:44:36	-0.488255769	0.603738129	**1:47:40**	0.421658754	-1	**1:50:44**	0.172907665	0.66576606
1:44:40	-0.467306376	0.560146749	**1:47:44**	0.458931178	-1	**1:50:48**	0.169177547	0.637140751
1:44:44	-0.446356952	0.514233649	**1:47:48**	0.508335829	-1	**1:50:52**	0.165447429	0.608515441
1:44:48	-0.4130027	0.468320578	**1:47:52**	0.557740569	-1	**1:50:56**	0.157423869	0.579890132
1:44:52	-0.379648447	0.415001124	**1:47:56**	0.597144008	-1	**1:51:00**	0.145106852	0.552354515
1:44:56	-0.350264937	0.3616817	**1:48:00**	0.626546264	-1	**1:51:04**	0.13278985	0.525908589
1:45:00	-0.324852169	0.30515483	**1:48:04**	0.65594852	-1	**1:51:08**	0.119439602	0.499462605
1:45:04	-0.299439371	0.245420575	**1:48:08**	0.685350776	-1	**1:51:12**	0.106089361	0.470760405
1:45:08	-0.276420414	0.18568632	**1:48:12**	0.714753032	-1	**1:51:16**	0.093734004	0.442058176
1:45:12	-0.253401428	0.122895144	**1:48:16**	0.74050355	-1	**1:51:20**	0.08237353	0.413355976
1:45:16	-0.235997632	0.060103972	**1:48:20**	0.762602329	-0.97870636	**1:51:24**	0.071013056	0.384653747
1:45:20	-0.224208981	-0.002687204	**1:48:24**	0.784701109	-0.93611902	**1:51:28**	0.066402741	0.355951548
1:45:24	-0.212420329	-0.065478377	**1:48:28**	0.789961636	-0.89353168	**1:51:32**	0.061792426	0.322619885
1:45:28	-0.189953625	-0.128269553	**1:48:32**	0.795222163	-0.829052925	**1:51:36**	0.057754796	0.289288223
1:45:32	-0.167486921	-0.187221318	**1:48:36**	0.800482631	-0.76457423	**1:51:40**	0.054289855	0.253437638
1:45:36	-0.142826483	-0.246173099	**1:48:40**	0.805743158	-0.70261246	**1:51:44**	0.050824914	0.215068132
1:45:40	-0.115972281	-0.301379919	**1:48:44**	0.811003685	-0.643167615	**1:51:48**	0.032275695	0.17669864
1:45:44	-0.089118078	-0.352841765	**1:48:48**	0.803021848	-0.58372277	**1:51:52**	0.013726478	0.247568995
1:45:48	-0.051507816	-0.40430361	**1:48:52**	0.795040011	-0.38856858	**1:51:56**	-0.01549956	0.318439364
1:45:52	-0.013897553	-0.506070197	**1:48:56**	0.783347011	-0.19341439	**1:52:00**	-0.05540242	0.372379243
1:45:56	0.024606951	-0.607836723	**1:49:00**	0.767942786	0.014713663	**1:52:04**	-0.095305279	0.409388632
1:46:00	0.064005695	-0.726976037	**1:49:04**	0.752538681	0.23581557	**1:52:08**	-0.147595808	0.44639802

Time	Average Signal	Aggressive Signal	Time	Average Signal	Aggressive Signal	Time	Average Signal	Aggressive Signal
1:46:04	0.10340444	-0.863488019	**1:49:08**	0.737134457	0.456917465	**1:52:12**	-0.199886322	0.454463124
1:46:08	0.128716543	-1	**1:49:12**	0.721730351	0.627764225	**1:52:16**	-0.253193676	0.462528199
1:46:12	0.154028639	-1	**1:49:16**	0.703573108	0.798610985	**1:52:20**	-0.307517886	0.456949353
1:46:16	0.168327719	-1	**1:49:20**	0.682662785	0.907227516	**1:52:24**	-0.361842066	0.437726557
1:46:20	0.171613783	-1	**1:49:24**	0.661752462	0.953613758	**1:52:28**	-0.406140238	0.418503761
1:46:24	0.174899846	-1	**1:49:28**	0.622421682	1	**1:52:32**	-0.45043838	0.38502875
1:46:28	0.192248181	-1	**1:49:32**	0.583090901	1	**1:52:36**	-0.481121004	0.351553738
1:46:32	0.2095965	-1	**1:49:36**	0.541712224	1	**1:52:40**	-0.498188049	0.315056801
1:46:36	0.231247053	-1	**1:49:40**	0.498285651	1	**1:52:44**	-0.515255094	0.275537908
1:46:40	0.254331678	-1	**1:49:44**	0.454859048	1	**1:52:48**	-0.541460395	0.236019015
1:46:44	0.281175584	-1	**1:49:48**	0.42924574	1	**1:52:52**	-0.567665756	0.198411077
1:46:48	0.319297343	-1	**1:49:52**	0.403632462	1	**1:52:56**	-0.586654127	0.160803139
1:53:00	-0.598425627	0.121021703	**1:56:04**	-0.082929432	0.080403879	**1:59:08**	0.02456098	0.641113877
1:53:04	-0.610197067	0.080515757	**1:56:08**	-0.064991727	0.083676063	**1:59:12**	0.016687235	0.608842731
1:53:08	-0.607450247	0.041958585	**1:56:12**	-0.047054026	0.080591008	**1:59:16**	0.012388599	0.576571584
1:53:12	-0.604703486	0.009247728	**1:56:16**	-0.033677049	0.077505961	**1:59:20**	0.011665074	0.541061342
1:53:16	-0.603474259	-0.023463132	**1:56:20**	-0.024860803	0.073420897	**1:59:24**	0.010941549	0.504471362
1:53:20	-0.603762627	-0.045611903	**1:56:24**	-0.016044557	0.069002487	**1:59:28**	0.002515012	0.470980912
1:53:24	-0.604050994	-0.064239979	**1:56:28**	-0.015577439	0.065084733	**1:59:32**	-0.005911525	0.446789086
1:53:28	-0.603355527	-0.080305971	**1:56:32**	-0.01511032	0.06266892	**1:59:36**	-0.026255293	0.422597289
1:53:32	-0.60266012	-0.088685706	**1:56:36**	-0.032246668	0.06025311	**1:59:40**	-0.058516294	0.404270113
1:53:36	-0.602907896	-0.097065449	**1:56:40**	-0.066986479	0.056998707	**1:59:44**	-0.090777293	0.387897789
1:53:40	-0.605985522	-0.10017506	**1:56:44**	-0.101726294	0.053464778	**1:59:48**	-0.121898793	0.372231752
1:53:44	-0.609063148	-0.101527974	**1:56:48**	-0.114221931	0.049645744	**1:59:52**	-0.153020293	0.35868451
1:53:48	-0.610770226	-0.102616608	**1:56:52**	-0.126717567	0.044971406	**1:59:56**	-0.182889059	0.345137268
1:53:52	-0.612477362	-0.102912426	**1:56:56**	-0.140705779	0.040297069	**2:00:00**[1]	-0.144251049	-0.282695264
1:53:56	-0.604503095	-0.103208244	**1:57:00**	-0.156186581	0.03658253			
1:54:00	-0.586847425	-0.105024494	**1:57:04**	-0.171667367	0.033187922			
1:54:04	-0.569191754	-0.107347548	**1:57:08**	-0.187148154	0.029289661			
1:54:08	-0.556356549	-0.109670602	**1:57:12**	-0.202628955	0.023880431			
1:54:12	-0.543521345	-0.111993663	**1:57:16**	-0.224631637	0.018471202			
1:54:16	-0.535643876	-0.114316717	**1:57:20**	-0.253156215	0.013061972			
1:54:20	-0.532724261	-0.112968408	**1:57:24**	-0.281680793	0.007652743			
1:54:24	-0.529804647	-0.110396303	**1:57:28**	-0.297771007	0.003055002			
1:54:28	-0.528995931	-0.106313333	**1:57:32**	-0.313861251	0.000891722			
1:54:32	-0.528187156	-0.09769775	**1:57:36**	-0.313938916	-0.001271558			
1:54:36	-0.531520784	-0.089082174	**1:57:40**	-0.298004061	0.001509728			
1:54:40	-0.538996816	-0.077713907	**1:57:44**	-0.282069206	0.005939202			
1:54:44	-0.546472788	-0.065428078	**1:57:48**	-0.260969162	0.016653111			
1:54:48	-0.546351671	-0.058191381	**1:57:52**	-0.239869133	0.046220332			
1:54:52	-0.546230555	-0.066102095	**1:57:56**	-0.220104992	0.075787552			
1:54:56	-0.542518675	-0.074012809	**1:58:00**	-0.201676756	0.178553477			
1:55:00	-0.535216033	-0.081923522	**1:58:04**	-0.18324852	0.305718958			
1:55:04	-0.527913392	-0.089834236	**1:58:08**	-0.16685003	0.42279774			
1:55:08	-0.516534984	-0.095007606	**1:58:12**	-0.150451541	0.509616375			

[1] Values for time 2:00:00 = time 0:00:00 and beyond simply repeat (e.g. 3:00:00 would equal 1:00:00)

Time	Average Signal	Aggressive Signal	Time	Average Signal	Aggressive Signal	Time	Average Signal	Aggressive Signal
1:55:12	-0.505156577	-0.091968976	**1:58:16**	-0.134967685	0.59643501			
1:55:16	-0.476738662	-0.088930346	**1:58:20**	-0.120398462	0.64934355			
1:55:20	-0.431281328	-0.082126252	**1:58:24**	-0.105829239	0.690948725			
1:55:24	-0.385823965	-0.074067011	**1:58:28**	-0.085855812	0.72519201			
1:55:28	-0.341343939	-0.062682293	**1:58:32**	-0.065882385	0.737349749			
1:55:32	-0.296863884	-0.04132114	**1:58:36**	-0.05748304	0.749507487			
1:55:36	-0.256356686	-0.01995999	**1:58:40**	-0.060657773	0.748818099			
1:55:40	-0.219822302	0.000250033	**1:58:44**	-0.063832507	0.743846297			
1:55:44	-0.183287933	0.020076348	**1:58:48**	-0.042603187	0.73644793			
1:55:48	-0.166973129	0.038548391	**1:58:52**	-0.021373866	0.72176981			
1:55:52	-0.150658324	0.052957628	**1:58:56**	-0.00212042	0.707091689			
1:55:56	-0.130586624	0.067366861	**1:59:00**	0.015157154	0.687150002			
1:56:00	-0.106758028	0.075012617	**1:59:04**	0.032434728	0.665453792			

Normative Appendix B

Duty-Cycle Signal for Islanded Microgrid Applications of Energy Storage Systems

Normative Appendix B

Duty-Cycle Signal for Islanded Microgrid Applications of Energy Storage Systems

The duty cycles to be applied in determining the performance of an ESS as an islanded microgrid were developed for three scenarios:

1. Microgrid with Renewables (where renewables consisted of a mix of solar and wind generation)
2. Microgrid with Renewables but no frequency regulation
3. Microgrid with no renewables and no frequency regulation

Each use case above involves storing some excess energy and providing it when needed, which is addressed in the peak shaving application criteria in the protocol. All of the above include VAR support, power quality, frequency response and black start.

Data used as the basis for the duty cycles presented in Section 5.3.3 are presented in the report, "Determination of the Duty Cycle for Energy Storage Systems Integrated with a Microgrid," PNNL-23390.

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