

DISAGGREGATION OF ELECTRICAL DATA FROM DISTRIBUTED ENERGY RESOURCES

TECHNICAL FIELD

5 The invention relates to a system of disaggregating electrical data from a plurality of distributed energy resource devices, to a multi-port electric meter, and to a method of disaggregating electrical data.

BACKGROUND

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The field of distributed energy resources (DERs) has been rapidly growing in recent years, as more and more buildings and homes are equipped with renewable energy sources such as solar panels, wind turbines, and battery storage systems. These DERs have the potential to significantly reduce energy costs and carbon emissions, but they
15 also present new challenges for energy management and grid stability.

One of the key challenges in managing DERs is the need to collect and analyze data from multiple devices in real-time. This data can include information on energy production, consumption, and storage, as well as environmental factors such as
20 temperature and humidity. Without accurate and timely data, it is difficult to optimize energy use, predict demand, and ensure grid stability.

To address this challenge, various systems have been developed for collecting and analyzing DER data. These systems can range from simple data loggers to complex
25 software platforms that integrate with building automation systems and utility networks. However, many of these systems have limitations in terms of scalability, interoperability, and data accuracy.

Improvements are desired to overcome these shortcomings and enable more efficient
30 and effective management of DERs.

SUMMARY

In general terms, the present disclosure is directed to a system for collecting and
35 analyzing electrical data from multiple distributed energy resource devices at a premises.

This system utilizes a multi-port electric meter and a data collector to classify the data and estimate the usage and generation of the devices. Advantageously, this invention solves the problem of accurately disaggregating and monitoring the energy consumption and production of various distributed energy resources devices, such as solar panels, batteries, and electric vehicle (ev) chargers, in a cost-effective and secure manner by utilizing a multi-port meter to collect data across multiple data channels of the multiport meter at a real time or near real time sampling rate, each port/channel corresponding to a circuit with one or more DER devices on it, as well as collect or receive non-meter data (such as historical weather forecast data including temperature, cloud cover, solar data, real-time weather data such as real-time temperature, cloud cover, solar data, location of the premises such as latitude and longitude, and others data sources such as one or more signals received from one or more of the DER devices indicating an operational state of the device such as an "on" or "off" state, or a percentage of charge of the DER device, voltage or current waveform data of the DER devices measured in real time or near real time during the transition time while the DER is tuning on or off as well as the steady-state consumption of the DER device) and to classify the sampled data into one or more classes (e.g. presence or absence of a DER device, and/or an estimate of a power usage or generation value from the DER device and/or the circuit it is on). By using not only the data measured by the multi-port electric meter but also other data such as that provided by signals indicative of an operational state of one or more of the DER devices, it becomes possible to disaggregate with much better accuracy the flow of energy to and from DER devices.

According to an aspect of the invention, there is provided a system for disaggregating electrical data from a plurality of distributed energy resource (DER) devices of a premises. The system comprises: a multi-port electric meter comprising: (i) a grid port configured for connecting the multi-port electric meter to an electric power grid, and (ii) one or more DER circuit ports each configured for connecting the multi-port electric meter to a circuit having two or more DER devices on at least one DER circuit port; a data collector configured to collect data from a plurality of data channels, at least one data channel comprising an electrical data channel and corresponding to a respective one of the plurality DER circuit ports, and at least one data channel comprising a non-electrical data channel; and a processor configured to: input the collected data from the plurality of data channels into a classifier to classify the collected electrical data into one or more classes; and estimating an electrical usage and/or generation value of one or more of the DER devices based on the output classification of the classifier.

Optionally, the non-electrical data channel comprises an environmental and/or geographical data channel.

- 5 Optionally, the collected non-electrical data comprises one or more of weather data and/or geographical location data

Optionally, the first sampling rate is between 1Hz and 1MHz.

- 10 Optionally, the processor is configured to perform the steps of inputting and estimating to provide continuous real-time or near-real-time estimation of the electrical usage and/or generation values of each DER devices and/or DER circuits.

- 15 Optionally, the one or more classes comprise one or more of: a presence or absence of an electric vehicle charger, a presence or absence of a battery system, and/or a presence or absence of a solar inverter, a presence or absence of an HVAC system, a presence or absence of a swimming pool pump, a presence or absence of a water heater, a presence or absence of a dishwashers, a presence or absence of a washer or dryer, and/or a presence or absence of a freezer or refrigerator.

- 20 Optionally, the system comprises one or more classes with an estimated electrical usage and/or generation value of one or more of the DER devices.

- 25 Optionally, at least one data channel comprises data received from at least one of the DER devices through a communication channel.

- 30 Optionally, the data received from at least one of the DER devices through the communication channel comprises measurement data obtained by the DER device and/or data indicating an operational state of the DER device. The operational state of the DER device may refer to, for example, an on or off state of the device, a percentage charge of the DER device, and/or any other data indicative of how the DER is or is not operating at a given time or times.

- 35 Optionally, the processor is located at said premises.

Optionally, the multi-port meter comprises a housing, and the processor and the data collector are provided in said housing.

5 Optionally, the processor is configured to generate a control signal based on a classification output of said classifier, and to transmit said control signal to one or more of said DER devices.

10 Optionally, the control signal includes instructions to turn one or more of the DER devices on or off, or to set the device to a predetermined electrical usage or generation value.

Optionally, the processor is configured to transmit the output classification result of the classifier, estimated electrical usage and/or generation value of one or more of the DER devices and/or DER circuits, to a provider of a power network supplying the premises.

15 According to an aspect of the invention, there is provided a multi-port electric meter for disaggregating electrical data from a plurality of distributed energy resource (DER) devices of a premises. The multi-port meter comprises a grid port configured for connecting the multi-port electric meter to an electric power grid; a one or more DER circuit ports each configured for connecting the multi-port electric meter to a circuit having
20 two or more DER devices thereon; a data collector configured to collect data from a plurality of data channels, at least one data channel comprising an electrical data channel and corresponding to a respective one of the plurality DER circuit ports, and at least one data channel comprising a non-electrical data channel; and a processor configured to input the collected data from the plurality of data channels into a classifier to classify the
25 collected electrical data into one or more classes and to estimate an electrical usage and/or generation value of one or more of the DER devices based on the output classification of the classifier.

30 Optionally, the first sampling rate is between 1Hz and 1MHz.

Optionally, the processor is configured to perform the steps of inputting and estimating to provide continuous real-time or near-real-time estimation of the electrical usage and/or generation values of the one or more DER devices.

Optionally, the processor is configured to generate a control signal based on a classification output of said classifier and to transmit said control signal to one or more of said DER devices.

- 5 Optionally, the control signal includes instructions to turn one or more of the DER devices on or off, or to set the device to a predetermined electrical usage or generation value.

10 According to an aspect of the invention, there is provided a method of disaggregating electrical data from a plurality of distributed energy resource (DER) devices of a premises. The method comprises: with a multi-port electric meter having a grid port connected to an electric power grid, one or more DER circuit ports each connected to a circuit having two or more DER devices thereon, and a data collector, collecting data from a plurality of data channels, at least one data channel comprising an electrical data channel and corresponding to a respective one of the plurality of DER circuit ports, and
15 at least one data channel comprising a non-electrical data channel; with a processor, inputting the collected data from the plurality of data channels into a classifier to classify the collected electrical data into one or more classes; and with the processor, estimating an electrical usage and/or generation value of one or more of the DER devices based on the output classification of the classifier.

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Optionally, the first sampling rate is between 1Hz and 1MHz.

Optionally, the method comprises performing the steps of inputting and estimating at a second sampling rate between 1Hz and 1MHz to provide continuous real-time or near-real-time estimation of the electrical usage and/or generation values of one or more of
25 the DER devices and/or DER circuits.

BRIEF DESCRIPTION OF THE DRAWINGS

30 These and other aspects will now be described in relation to the Figures in which:

Figure 1 illustratively shows a system for disaggregating electrical data from a plurality of distributed energy resource (DER) devices of a premises according to the present disclosure.

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Figure 2 illustratively shows a multi-port electric meter according to the present disclosure.

5 Figure 3 illustratively shows a method of disaggregating electrical data from a plurality of distributed energy resource (DER) devices of a premises according to the present disclosure.

Figure 4 illustratively shows an example architecture according to the present disclosure.

10 Figure 5 illustratively shows an example architecture according to the present disclosure.

Figure 6 illustratively shows a flowchart of a method according to the present disclosure.

15 Figure 7 illustratively shows a flowchart of a method according to the present disclosure

DETAILED DESCRIPTION

Figure 1 illustratively shows a system 100 for disaggregating electrical data from a plurality of distributed energy resource (DER) devices 102a, 102b, on a DER circuit (i.e. a circuit with multiple DER devices connected to it) of a premises according to the present disclosure. The system 100 comprises a multi-port electric meter 103 having a grid port 104 to connect the multi-port electric meter to a grid 104a of a power network and one or more of DER circuit ports 105a, a data collector 106 configured collect electrical data from the one or more DER circuit ports 105a, as well as collect other non-electrical data from one or more other data sources (such as environmental and geographic data, for example weather and/or location data), and a processor 107. The multi-port electric meter 103 in Figure 1 also has a non-DER port 105b through which one or more non-DER devices 102c may be connected. The processor 107 is configured to input the collected data into a classifier to classify the collected electrical data into one or more classes, and estimate an electrical usage and/or generation value of one or more of the DER devices 102a, 102b based on the output classification of the classifier.

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Whilst only one DER circuit is shown in Figure 1, it is envisaged that this may be extended to multiple DER circuits whereby the same advantages described herein are applicable to systems with a plurality of DER circuits and accordingly a plurality of DER circuit ports on the multi-port electric meter.

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It is also envisaged that the present disclosure may be used to not only disaggregate data of the DER devices on the DER circuit through the DER circuit ports, but also to disaggregating data from non-DER devices on the non-DER device port of the multi-port meter.

Advantageously, as the disaggregation of the electrical data runs inside a compute enabled, power network edge intelligence device (i.e. the multi-port meter is provided with a microprocessor unit (MPU) or microcontroller unit (MCU)), the system can facilitate locally utilizing and processing collected data from the multiple data channels, without reliance on a cloud infrastructure. Additionally or alternatively, cloud infrastructure may be used to augment the capabilities of the system, for example by externally collecting, storing, streaming and/or processing data that may be used as a data channel input into the classifier. Further, the multi-port electric meter is different from traditional single-channel meters, as it allows monitoring of multiple channels, with one channel for the home's traditional electrical usage and additional channels for DER devices such as solar panels, batteries, and electric vehicle (ev) chargers, HVAC systems, pool pumps, water heaters, dishwashers, washer/dryer, freezers, refrigerators, and any other large home loads and so on, as well as channels for non-electrical data (such as weather and location data) that may be correlated with the electrical data. This enables the system to more accurately estimate the electrical usage and/or generation value of each DER device 102a, 102b and non-DER device 102c, as variety and number of data channels and data sources facilitates higher accuracy estimates than in systems that rely on electrical data only.

In some embodiments, the first sampling rate is between 1Hz and 1MHz. In some embodiments, the processor 107 is configured to perform said steps of inputting and estimating to provide continuous real-time or near-real-time estimation of said electrical usage and/or generation values of each said DER devices 102a, 102b on the DER circuits.

Advantageously, the system's 100 higher sampling rate, as compared to existing technologies that use sampling rates of minutes to days to weeks to months sampling and inference rates, allows for disaggregation of electrical data in real-time or near-real-time. This enables the system to detect changes in electrical usage, such as a 4kW increase that may indicate an EV charger is in use, at second or faster intervals, by

analyzing the data from the DER data channel and the other data channels. It also facilitates the incorporation of more granular real-time weather data into a data channel that may enhance the accuracy of the output classification that is not possible at lower sampling rates of days, weeks, months etc. In a specific, non-limiting, illustrative
5 example, a solar panel and inverter may be present in a DER circuit and cloudy weather conditions with intermittent spells of sun may result in peaks and dips in solar inverter output. Electrical data and weather data sampled at the above rates of between 1Hz and 1MHz is better able to capture granular changes in real-time.

It will be appreciated that the classifier envisaged herein is trained on a training data set
10 that comprises data matching the sampling rate and type of the data which it will receive when performing inference. That is, if data sampled at 1Hz is input into the classifier, the classifier is envisaged to have been trained on training data also sampled at 1Hz (or synthetically generated to simulate such data). Conversely if data sampled at 1MHz is input into the classifier, the classifier is envisaged to have been trained on 1MHz sampled
15 (or synthetic) data and so on. Equally, the training data set comprises the same types and number of non-electrical data channel types (e.g. weather, location, and so on) as that which is envisaged to be used during inference.

In some embodiments, the one or more classes comprise one or more of: a presence or
20 absence of an electric vehicle charger, a presence or absence of a battery system, and/or a presence or absence of a solar inverter, a presence or absence of an HVAC system, a presence or absence of a swimming pool pump, a presence or absence of a water heater, a presence or absence of a dishwashers, a presence or absence of a washer or dryer, and/or a presence or absence of a freezer or refrigerator, and so on. In
25 some embodiments, the system 100 comprises one or more classes that include an estimated electrical usage and/or generation value of one or more of the DER devices 102a, 102b.

Advantageously, the system 100 can classify the electrical data into various classes, the
30 classes corresponding to the presence or absence of specific DER devices, such as electric vehicle chargers, battery systems, and solar inverters. This allows the system 100 to more accurately estimate the electrical usage and/or generation value of each DER device 102a, 102b, improving the overall efficiency and effectiveness of the system. Specifically, making a simple classification about the presence or lack of one or more
35 DER device types that typically makes up the majority of usage or generation on a DER circuit (e.g. ev charges, solar invertors, and/or battery systems), allows further

information to be inferred. For example, making a classification that a solar inverter and ev charger but no battery system are present on a DER circuit, allows the inference to be made that any usage or generation will be entirely due to the solar inverter and/or electric vehicle charger, so any signals that might otherwise have been mischaracterised as being indicative of the presence of a battery system when disaggregating the data can be ignored. Conversely, if the classification is made that a solar inverter, an electric vehicle charger, and a battery system is present on a DER circuit, then it is possible to infer that uniquely identifiable signal features associated with such devices may be present in the data channels which accordingly may be used to disaggregate the data.

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In some embodiments, the processor 107 is further configured to receive weather data associated with a geographic location of the system for inputting into the classifier, whereby said weather data is a further data channel.

Advantageously, as described above the system 100 can incorporate weather data, such as temperature, cloud cover, and solar forecasts, to improve the accuracy of the disaggregation. By combining this weather data with the sampled electrical data, the system can better estimate the electrical usage and/or generation value of each DER device 102a, 102b, and taking into account the impact of weather conditions on the performance of these devices. This allows for a more accurate and efficient management of the electrical data from the DER devices. Specifically, certain signals in data collector data are likely to be correlated e.g. cloud cover and a drop in solar inverter output, freezing temperatures and an increase power consumption of an electric vehicle charger, and so on. Incorporating this data as a data channel into the system, allows for the information from these correlations to be captured in the training of the classifier, and accordingly in the ability of the classifier to more accurately make a classification when encountering such data during inference.

In some embodiments, the processor 107 is configured to receive data indicative of a state of one or more of the DER devices and/or measurement data from and obtained by one or more of the DER devices for inputting into the classifier, whereby this state and/or measurement data are further data channels. Advantageously, this allows the system to incorporate additional information from the DER devices themselves, such as on/off indicators, charge percentage indicators (e.g. state of charge), or signals corresponding to solar output (e.g. irradiance). By combining this DER state and/or measurement data with the sampled electrical data, the system can improve the

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accuracy of the disaggregation and better estimate the electrical usage and/or generation value of each DER device 102a, 102b. This is particularly useful in scenarios where the DER devices have multiple levels of charging or varying output levels, and/or has its own metrology as the additional information provided in the further data channels, such as the operational state of the DER device and/or any other data received from the DER device improves the accuracy of the disaggregation estimate.

In some embodiments, the processor 107 is located at the premises the system 100 is located at, rather than in the cloud. Advantageously, this allows for faster processing and communication between the DER devices and the processor 107, as well as reduced latency in the system more generally as it need not rely on cloud-based compute resources. By having the processor 107 located at the premises, the system can accordingly more efficiently manage the electrical data from the DER devices and provide real-time or near-real-time estimation of electrical usage and/or generation values. However, it is also envisaged that in some alternative embodiments, one or more additional processors may be provided and located in the cloud, or elsewhere, on a network with the system to allow compute resources to be distributed across a number of devices.

In some embodiments, the multi-port electric meter 103 comprises a housing, wherein the processor 107 and the data collector 106 are provided in said housing. Advantageously, this provides a compact, integrated, single piece of equipment that allows for easier installation and maintenance of the system 100, as well as improved communication between the processor 107 and the data collector 106 as the main functional components of the system 100 are on-board of a single, convenient device (the multi-port meter 103), rather than being dispersed across different locations and servers in a distributed manner in the cloud. Specifically, by housing the processor 107 and data collector 106 together, the system 100 can more efficiently sample and process the electrical data from the DER devices, leading to more accurate disaggregation and estimation of electrical usage and/or generation values.

In some embodiments, the processor 107 is further configured to generate a control signal based on a classification output of said classifier, and to transmit said control signal to one or more of said DER devices. The control signal may comprise, for example, instructions to turn one or more of the DER devices on or off, or to set the device to a predetermined electrical usage or generation value. Advantageously, this allows the

system to actively manage the DER devices based on the disaggregated electrical data and classification results, without relying on external control signals received via the cloud or other communication channel. By generating and transmitting control signals to the DER devices, the system can optimize the usage and/or generation of electricity,
5 improving the overall efficiency and effectiveness of the system.

In some embodiments, the processor 107 is further configured to transmit the output classification result of the classifier and/or the estimated electrical usage and/or generation value of one or more of the DER devices 102a, 102b and/or DER circuits to
10 a provider of a power network 104a supplying the premises. Advantageously, this allows the power network provider to have access to detailed information about the electrical usage and/or generation of the DER devices, enabling better management and optimization of the power network. By sharing this information with the power network provider, the system can contribute to a more efficient and reliable power grid, benefiting
15 both the premises and the larger community. For example, the power network provider may override any control signals generated by the processor to allow manual management of the power network. Further envisaged use cases include using the disaggregated DER data to facilitate billing/paying at specific rates for different DER devices (e.g. for EV charging, solar generation, and so on), as well as to calculate any
20 applicable renewable energy credits if such a scheme is in operation where the system is located. More particularly, by relying on multiple electrical and non-electrical data channels, the accuracy of the DER data disaggregation may be greater than a predetermined percentage (e.g. 2%), thereby allowing it to be used for billing purposes. Something which is often not possible with existing disaggregation techniques that rely
25 only on electrical data channels. Further, where DER devices have their own metrology which is controlled by the DER device provider, it can be present some difficulties for a utility provider, in that accessing this metrology is often costly, presents security issues, and the accuracy cannot be guaranteed. One existing solution to this, is to provide each DER with its own highly accurate (e.g. revenue grade, >2% accuracy) dedicated meter
30 to measure its consumption and/or production. However this solution is expensive and complex. Accordingly disaggregation according to the present disclosure facilitates high consumption and/or production estimation accuracy to be achieved without the need for separate, dedicated meter hardware for each device. It is however also envisaged that, a multi-port electric meter of the present invention could in some embodiments be
35 provided with a dedicated DER port for each device e.g. if there are 2 DER devices, the

meter may be provided 2 DER ports, each providing accurate, direct consumption and production measurements associated with the connected DER device.

Figure 2 illustratively shows a multi-port electric meter 203 according to the present disclosure. The multi-port electric meter 203 comprises a grid port 204, a non-DER device port 205a, a DER circuit port, 205ba data collector 206, and a processor 207. The grid port 204 is configured for connecting the multi-port electric meter 203 to an electric power grid. The DER circuit port 205bis configured for connecting the multi-port electric meter 203 to a circuit having two or more DER devices 102b, 102c thereon. The data collector 206 is configured to collect data from a plurality of data channels, at least one data channel comprising an electrical data channel corresponding to a respective one of the DER circuit ports 205b, and at least one data channel comprising a non-electrical data channel. The processor 207 is configured to input the collected data from the plurality of data channels into classifier to classify the collected electrical data into one or more classes and estimate an electrical usage and/or generation value of one or more of the DER devices and/or DER circuits based on the output classification of the classifier.

Advantageously, as described above the multi-port electric meter 203 allows for the monitoring of multiple data channels, including electrical and non-electrical data (e.g. weather, location, operational state of the DER device as described above, and so on), as opposed to traditional single-channel meters. This enables the meter 203 to more accurately estimate the electrical usage and/or generation value of each DER device, such as solar panels, batteries, and electric vehicle (ev) chargers, and others. Thereby allowing the system to more accurately disaggregate the electrical data and improve the overall efficiency and effectiveness of the system.

In some embodiments, the first sampling rate is between 1Hz and 1MHz. In some embodiments, the processor is configured to perform said steps of inputting and estimating to provide continuous real-time or near-real-time estimation of said electrical usage and/or generation values of the one or more of the DER devices.

Advantageously, as described above this sampling rate facilitates disaggregation of electrical data in real-time or near-real-time, and processed locally to avoid the need of relying on the cloud for compute power.

In some embodiments, the processor 207 is further configured to generate a control signal based on a classification output of said classifier, and to transmit said control signal to one or more of said DER devices. In some embodiments, the control signal comprises instructions to turn one or more of the DER devices on or off, or to set the
5 device to a predetermined electrical usage or generation value.

Advantageously, the system can generate control signals based on the classification output of the classifier, allowing for more efficient management of the DER devices. This can include turning devices on or off or setting them to predetermined electrical usage
10 or generation values. By incorporating the various inputs listed in the present disclosure, the system can more accurately control the DER devices, leading to improved energy management and potential cost savings for the user.

Figure 3 illustratively shows a flowchart of a method 300 of disaggregating electrical data from a plurality of distributed energy resource (DER) devices of a premises according to
15 the present disclosure. The method 300 includes using a multi-port electric meter having a grid port connected to an electric power grid, at least one DER circuit port each connected to a circuit having two or more DER devices thereon, and a data collector. The data collector collects 301 data from a plurality of data channels, at least one data
20 channel comprising an electrical data channel and corresponding to a respective one of the plurality of DER circuit ports, and at least one data channel comprising a non-electrical data channel. The method 300 then comprises inputting 302 the collected data from the plurality of data channels into classifier to classify the collected electrical data into one or more classes, and estimating 303 an electrical usage and/or generation value
25 of one or more of the DER devices based on the output classification of the classifier.

In some embodiments, the first sampling rate is between 1Hz and 1MHz. In some embodiments, the method comprises performing the steps of inputting and estimating at a second sampling rate of between 1Hz and 1MHz to provide continuous real-time or
30 near-real-time estimation of the electrical usage and/or generation values of one or more of the DER devices.

Advantageously, the method of disaggregating electrical data using a multi-port electric meter and multiple data channels (including electrical and non-electrical data channels)
35 allows for more accurate estimation of electrical usage and/or generation values of DER devices. The method facilitates the detection of changes in electrical usage, such as a

4kW increase that may indicate an ev charger is in use, by analyzing the data from one or more of the data channels. The method may accordingly incorporate solar data and other inputs, such as historical data, weather forecast, real-time cloud cover, solar forecast, location of the home, input signal from DER devices, on/off indicator from ev
5 chargers or battery system chargers, charge % indicator from ev chargers or battery system chargers, and signals from solar inverters corresponding to solar output, to improve the accuracy of the disaggregation. This method can be applied in various scenarios, as described in the present disclosure examples, to better estimate the electrical usage and/or generation value of each DER device, improving the overall
10 efficiency and effectiveness of the system.

Figure 4 illustratively shows a flowchart of a classifier architecture 400 that may be used with the present disclosure.

15 The architecture 400 comprises a plurality of input data channels 401a, 401b, 401c, such as those described above for example corresponding to each of the DER circuit ports of the multi-port meter and to other input data channels such as the operational state of one or more DER devices connected to the DER circuit ports, waveform data measured in real time or near real time during the transition time while the DER devices are tuning
20 on or off, as well as the steady-state consumption of the DER devices, weather data, historical usage and generation and so on. The data from the input data channels is passed to a low-level feature detection component 402 that is configured to extract low-level features from the input data channels 401a, 401b, 401c. The extracted low-level features are then passed to a high-level feature detection component 403 that is
25 configured to extract high-level features from the input data channels 401a, 401b, 401c. The extracted high-level features are then passed to a temporal sequencing component 404 before being passed to a classification component 405. The classification component 405 outputs a classification result, for example an output class of whether or not a given DER device type is present or not, and/or a sub-type of that device, and or
30 an estimated usage or generation value of the device for the given sampling time period.

It is envisaged that the low-level feature detection component 402, high level feature detection component 403, temporal sequencing component 404, and classification component 405 may be standalone models, trained separately, where the output of one
35 model is passed into the input of the next model, or they may be integrated in a single model whereby all weights, biases and other parameters of the single model may be

iteratively adjusted together. The components may comprise one or more of recurrent neural networks and convolutional neural networks, and the final output layer of the classification component 405 may be a softmax layer.

5 Figure 5 illustratively shows a machine learning model architecture 500 for energy forecasting according to the present disclosure. Illustrated are a number of inputs which may be in the form of vectors (e.g. embeddings) of n-dimensions which may comprise one or more of the following: one or more vectors 501a of recent historical energy values, one or more vectors 501b of weather forecast data (e.g. temperature, solar irradiance,
10 and other weather data), one or more vectors of temporal information (e.g. day of the week, week of the year, and so on), one or more vectors of geographic location (e.g. latitude and/or longitude data). As described above, it is envisaged that other input data sources and types may also be provided, the operational state of one or more DER devices connected to the DER circuit ports, waveform data measured in real time or near
15 real time during the transition time while the DER devices are tuning on or off, as well as the steady-state consumption of the DER devices. The input vectors are fed into a machine learning model 502 suitable for regression. This may be for, example, one or more of the following models: a decision tree model, a random forest model, a support vector machine (SVM) model, an XGBoost model, a long short-term memory (LSTM)
20 model, an autoregressive integrated moving average (ARIMA) model. It will be appreciated that in each case, the model used will be trained on a suitably sized training data set to achieve a desired performance in terms of one or more of accuracy, precision, recall, and/or other machine learning model performance metric as applicable. It is envisaged that the output of the model comprises a vector comprising predicted energy
25 values i.e. values indicative of energy consumption and/or generation.

Figure 6 illustratively shows a flowchart of a method according to the present disclosure with which determinations or classifications as to energy consumption and/or generation can be made in a case where there are two DER devices (a battery system such as an
30 EV or stationary battery system, and a solar inverter) connected to a single DER circuit port of the electric meter. In this example, it is determined 601 from one input data channel (e.g. weather, time and/or geographic data) that the sun is down and accordingly that a solar inverter is not outputting energy, and from another input data channel that consumption of energy is below a threshold value. In this case, it can be determined
35 simply that the battery system is not charging. Specifically, it can be determined that all

the DER devices are off. In this case, the power draw of the system can be set 602 to a nominal current draw of the devices (e.g. an always-on load value).

Figure 7 illustratively shows a method according to the present disclosure with which
5 determinations or classifications as to energy consumption and/or generation can be made again in a case where there are two DER devices (a battery system such as an EV or stationary battery system, and a solar inverter) connected to a single DER circuit port of the electric meter. In this example, it is determined 701 from one data channel (e.g. an input signal from DER device indicating an operational state change of the DER
10 device) that the one or more DER devices' states have changed. The multi-port electric meter at the same time detects and measures 702 an increase in consumption on the DER circuit port, indicative that the battery system is drawing power. The method of Figure 6 is then used to determine 703 whether or not it can be determined what devices on the DER circuit are off (e.g. in the case of the solar inverter by using weather, time
15 and/or geographic data as described above). Once this determination is made, the nominal (e.g. always-on load) value is then subtracted 704 from the consumption measurement of the multi-port electric meter and the resulting value will be the power value that can be assigned 705 to the power draw of the (charging) battery system. Next, another input data channel (e.g. a presence or lack of a signal from one or more of the
20 DER devices indicating an operational state thereof) is used to determine 706 if the charging battery system is being provided with a predetermined percentage of charge. If yes, the amount that is meant to be provided according to the signal received from the DER device is correlated 707 with the actual percentage of charge being provided, and the signature including waveform data during power up of the DER device is assigned
25 708 as a power draw value to the battery system. If no, it is determined 709 whether or not the battery system has more than one charge level. If there are multiple charge levels available, the resulting power draw value is assigned 710 to one of the charge levels of the battery system and the signature including waveform data during power up of the DER device is assigned 709 as a power draw value to the battery system. If there are
30 not multiple levels, the resultant value is assigned 711 to the power draw of the battery system, and the signature including waveform data during power up of the DER device is assigned 708 as a power draw value to the battery system.

It will be understood that the term "classifier" as used herein may refer to an algorithm,
35 software, or hardware component within the system that processes and categorizes the

collected electrical data from the distributed energy resource devices into one or more classes.

5 It will be understood that the term "control signal" as used herein may refer to an electrical or digital signal that is transmitted to the distributed energy resource devices in order to regulate their operation, such as adjusting power output, switching on or off, or modifying other operational parameters.

10 It will be understood that the term "estimated usage/generation value" as used herein may refer to the calculated amount of electrical energy used by or produced by the distributed energy resource devices on a premises, based on the collected and analyzed data from the multi-port electric meter and/or other data sources.

15 It will be understood that the term "plurality of data channels" as used herein may refer to multiple communication pathways or connections through which the collection, transmission, and analysis of electrical and other data from various distributed energy resource devices occurs.

20 It will be understood that were it is described herein that data is available to a utility provider, this need not be solely limited to data at the point of supply or consumption, but may also include other data sources, such as localised carbon intensity scores and/or other metrics which may be available to the utility provider in some locations and jurisdictions.

25 A number of illustrative example use cases of the present disclosure are now described.

Example 1: There is a solar inverter and an EV charger connected to a single measurement port of the electric meter. There are no signal (communication) connections between either DER device and/or the meter. The EV charger only charges at one level when it charges. The present system identifies times when the EV charger is on (indicated by delivered load) when the Inverter could not be outputting energy (determined by using location and other almanac data to determine the daily times when it is dark outside and therefore the solar panels will not be outputting energy). If the power flow is in the 'delivered' direction (i.e. power flowing away from the utility), that indicates that a load must be on. If the power flow is above the threshold of the nominal power draw of the connected devices (defined as the power draw of the inverter + EV charger

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themselves with no solar input and with no charging output to the EV), then the EV charger must be in the charging state. If the power flow is in the 'received' direction (energy flowing toward the utility), then the solar inverter must be receiving power from the solar panels, or the EV charger could be discharging utilizing V2X technology. The models of the present disclosure are accordingly able to learn the signature of the EV charger including what the start-up looks like and what the actual load is when on, and would allocate this to the EV while leaving the rest remainder allocated to solar. The signature of the EV charger would include one or more of the following: a recognizable voltage and current waveform shape when the charger starts charging, the steady-state power draw during charging (one or more levels depending on whether just one or more than one level is supported by the charger), and the waveform shapes when the charger stops charging.

Example 2: the present disclosure includes a signal from the EV charger to indicate its operational state (e.g. when it is charging). In this case, the signal from the EV charger would indicate simply whether the EV charger was charging or not. This signal would be used by present disclosure to determine if the EV charger was charging, and the present disclosure determines how much power (W or kW) the EV charger is consuming at each given time based on the learning done during times when the sun is down.

Example 3: similar to example 2 but the EV charger would have multiple levels of charging and would have either an on/off signal or a signal indicating charge level that the present disclosure would take as an input take into account. The present disclosure is able to correlate charge level to a power consumption value of the EV charger utilizing data from times when the sun is down, and potentially some interpolation.

Example 4: similar to example 1 but the present disclosure uses weather data and historical learnings to estimate the solar output and to better determine when the EV charger is charging. For example, weather data may include temperature and cloud cover. The algorithm could use existing models to determine solar irradiance based on these inputs and the angle of the sun at that particular time and day for the given location. The present disclosure could also compare actual power output vs. predicted power output and predicted solar irradiance to further train its models and improve accuracy over time. When the power varies from this predicted solar inverter power output by the power that corresponds to one or more possible charging levels of the EV charger, this power would be attributed to the EV charger.

Example 5: the system may also include a stationary battery used for energy storage could be added to the system. That signature to charge the battery would look similar to the signature to charge.

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Example 6: the EV or stationary battery charger and/or solar inverter could have its own metrology, and the present disclosure is able to improve upon the accuracy of the metrology. The metrology from the EV or stationary battery charger and/or solar inverter would send its real-time readings to the meter, and the algorithm running inside the meter would either take this metrology data directly, or use the data as an input to an algorithm that may correct the actual metrology reading to provide a power breakdown of the various devices.

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It will be appreciated by the person of skill in the art that various modifications may be made to the above-described examples without departing from the scope of the invention as defined by the appended claims.

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CLAIMS:

1. A system for disaggregating electrical data from a plurality of distributed energy resource (DER) devices of a premises, the system comprising:
 - 5 a multi-port electric meter comprising: (i) a grid port configured for connecting the multi-port electric meter to an electric power grid, and (ii) one or more DER circuit ports each configured for connecting the multi-port electric meter to a circuit having two or more DER devices on at least one DER circuit port;
 - a data collector configured to collect data from a plurality of data channels, at
10 least one data channel comprising an electrical data channel and corresponding to a respective one of the DER circuit ports, and at least one data channel comprising a non-electrical data channel; and
 - a processor configured to:
 - input the collected data from the plurality of data channels into a classifier
15 to classify the collected electrical data into one or more classes; and
 - estimating an electrical usage and/or generation value of one or more of the DER devices based on the output classification of the classifier.
2. The system of claim 1, wherein the at least one data channel comprising a non-
20 electrical data channel comprises an environmental and/or geographical data channel.
3. The system of claim 2, wherein the collected non-electrical data comprises one or more of weather data and/or geographical location data.
- 25 4. The system of claim 1, wherein the data collector collects data in said electrical data channel at a first sampling rate, and wherein first sampling rate is between 1 Hz and 1 MHz.
5. The system of claim 4, wherein the processor is configured to perform said steps
30 of inputting and estimating to provide continuous real-time or near-real-time estimation of said electrical usage and/or generation values of each said DER devices.
6. The system of claim 1, wherein the one or more classes comprise one or more
35 of: a presence or absence of an electric vehicle charger, a presence or absence of a battery system, a presence or absence of a solar inverter, a presence or absence of an HVAC system, a presence or absence of a swimming pool pump, a presence or absence

of a water heater, a presence or absence of a dishwashers, a presence or absence of a washer or dryer, and/or a presence or absence of a freezer or refrigerator.

7. The system of claim 1, wherein the one or more classes comprise an estimated
5 electrical usage and/or generation value of one or more of the DER devices.

8. The system of claim 1, wherein at least one data channel comprises data
received from at least one of the DER devices through a communication channel.
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9. The system of claim 8, wherein the data received from at least one of the DER
devices through the communication channel comprises measurement data obtained by
the DER device and/or data indicating an operational state of the DER device.

10. The system of claim 1, wherein the processor is located at said premises.
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11. The system of claims 10, wherein the multi-port meter comprises a housing, and
wherein the processor and the data collector are provided in said housing.

12. The system of claim 1, wherein the processor is further configured to generate a
control signal based on a classification output of said classifier, and to transmit said
control signal to one or more of said DER devices.
20

13. The system of claim 12, wherein the control signal comprises instructions to turn
one or more of said DER devices on or off, or to set the device to a predetermined
electrical usage or generation value.
25

14. The system of claim 1, wherein the processor is further configured to transmit the
output classification result of the classifier and/or the estimated electrical usage and/or
generation value of one or more of the DER devices to a provider of a power network
supplying the premises.
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15. A multi-port electric meter for disaggregating electrical data from a plurality of
distributed energy resource (DER) devices of a premises, the multi-port meter
comprising:
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a grid port configured for connecting the multi-port electric meter to an electric power grid;

one or more DER circuit ports each configured for connecting the multi-port electric meter to a circuit having two or more DER devices on at least one DER circuit port;

a data collector configured to collect data from a plurality of data channels, at least one data channel comprising an electrical data channel and corresponding to a respective one of the plurality DER circuit ports, and at least one data channel comprising a non-electrical data channel; and

a processor configured to:

input the collected data from the plurality of data channels into a classifier to classify the collected electrical data into one or more classes; and

estimating an electrical usage and/or generation value of one or more of the DER devices based on the output classification of the classifier.

16. The multi-port electric meter of claim 15, wherein the first sampling rate is between 1Hz and 1MHz.

17. The multi-port electric meter of claim 16, wherein the processor is configured to perform said steps of inputting and estimating o provide continuous real-time or near-real-time estimation of said electrical usage and/or generation values of the one or more of the DER devices.

18. The multi-port electric meter of claim 15, wherein the processor is further configured to generate a control signal based on a classification output of said classifier, and to transmit said control signal to one or more of said DER devices.

19. The multi-port electric meter of claim 18, wherein the control signal comprises instructions to turn one or more of said DER devices on or off, or to set the device to a predetermined electrical usage or generation value.

20. A method of disaggregating electrical data from a plurality of distributed energy resource (DER) devices of a premises, the method comprising:

with a multi-port electric meter having a grid port connected to an electric power grid, one or more DER circuit ports each connected to a circuit having two or more DER devices on at least one DER circuit port, and a data collector, collecting data from a

plurality of data channels, at least one data channel comprising an electrical data channel and corresponding to a respective one of the plurality of DER circuit ports, and at least one data channel comprising a non-electrical data channel;

- 5 with a processor, inputting the collected data from the plurality of data channels into a classifier to classify the collected electrical data into one or more classes; and
- with the processor, estimating an electrical usage and/or generation value of one or more of the DER devices based on the output classification of the classifier.