

FLOW FRAME FOR REDOX FLOW BATTERY AND REDOX FLOW BATTERY

TECHNICAL FIELD

- 5 The present disclosure relates to redox flow batteries and in particular to flow frames for redox flow batteries.

BACKGROUND

- 10 Flow batteries, also known as redox flow batteries or redox flow cells, are designed to convert electrical energy to chemical energy that can be stored and later used upon demand. The vanadium redox flow battery (VRFB) is one of the most popular battery among the flow batteries in the market. VRFB can be used in both grid applications (daily peak shifting and balancing intermittency) and off-grid/micro-grid applications
15 (balancing renewables). The major advantages of VRFB over other types of batteries are long lifetime, stable performance, fast response, cheaper levelized cost of storage (LCOS) and ease of scalability.

- A basic flow battery single cell comprises positive and negative electrodes separated
20 by an ion exchange membrane. Positive and negative electrolytes are circulated to the respective electrodes through a flow frame to drive reversible redox reactions.

- A redox flow battery is composed of plurality of the cells in series, known as a stack. Being the core component in the VRFB, the battery stack serves as an electrochemical
25 reactor. Energy is stored chemically by redox species dissolved in the electrolyte which is supplied from separate tanks outside of the reactor. Accordingly, the capacity/energy scales with the size of the tanks and the concentration of redox species and, hence, the energy and power rating of the battery can be tailored.

- 30 The scaling up of stack power to large size stack with higher power rating is attractive for reducing the cost, footprint and simplifying the electronics, but this poses several challenges such as poor flow distribution of electrolyte, increased self-discharge and large pumping power. Out of the various problems, the likelihood of non-uniform flow distribution significantly increase as the stack size becomes larger.

SUMMARY

According to a first aspect of the present disclosure a flow frame for a redox flow battery is provided. The flow frame forms a rectangular cavity configured to receive at least one porous electrode. The flow frame comprises: an inlet for receiving an electrolyte liquid; a plurality of supply channels coupling the inlet to a plurality of supply channel openings arranged along a supply side of rectangular cavity; an outlet for discharging the electrolyte liquid; and a plurality of discharge channels coupling the outlet to a plurality of discharge channel openings arranged along a discharge side of the rectangular cavity, the discharge side of the rectangular cavity being opposite the supply side, wherein a length of the rectangular cavity corresponding to a length of the supply side and the discharge side is at least twice a width of the rectangular cavity corresponding to a separation of the supply side from the discharge side.

The relationship between the size of the length of the rectangular cavity and the width of the rectangular cavity minimizes pump losses and therefore provides for an efficient redox flow battery.

In an embodiment, the flow frame further comprises a plurality of vanes provided in front of the supply channel openings and / or the discharge channel openings. The provision of vanes results in a more uniform distribution of electrolyte across the electrode or electrodes provided in the flow frame.

The vanes may be provided in two rows in front of the of the supply channel openings and / or the discharge channel openings. Having a double row structure of vanes increases the flow resistance thereby minimizing the current leakage or shunt losses ultimately resulting in better columbic efficiency. The two rows of vanes may be arranged in an offset manner.

The vanes may have a length in a direction parallel to the supply side and the discharge side of the rectangular cavity which is greater than a width of the vanes in a direction perpendicular to the supply side and the discharge side of the rectangular cavity. The length of the vanes is at least 5mm and / or less than 20mm. The width of

the vanes is at least 2mm and / or less than 8mm. The vanes may have a height of at least 1mm and less than 6mm.

5 The discharge channels and / or the supply channels may have a width of at least 1mm and / or less than 3mm. The discharge channels and / or the supply channels may have a depth of at least 1mm and / or less than 3mm.

The supply channels and / or the discharge channels may each run separately from the inlet / the outlet to a respective channel opening.

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In an embodiment, the flow frame further comprises a divider running from the supply side of the rectangular cavity to the discharge side of the rectangular cavity which divides the rectangular cavity into sub-cavities. The divider provides additional support to bipolar plate and also aids in preventing the bipolar plate from tearing and breaking
15 due to buckling in the event of using thin bipolar plates. The divider also allows the porous electrode to be used in two separate pieces which is easier for handling and treatment. The divider also helps to divide the hydraulic circuit within the cell ensuring improved flow distribution and reduced zone with stagnant flow. The divider also provides higher possibility of uniform electrolyte distribution as it divides cavity into
20 separate zones (left and right), reducing the chance of unutilized portion of electrode.

In an embodiment the flow frame is provided with a plurality of protrusions on sides of the rectangular cavity configured to engage with the at least one porous electrode. When the flow frame comprises a divider, the protrusions may be provided on the
25 divider and / or on the sides of the rectangular cavity. The protrusions act as hooks to prevent the fall of porous electrode during the assembly of cell/stack avoiding need of any sticky tape, glue or external holders. The protrusions may be rectangular or triangular in shape. The protrusions may extend into the cavity by at least 5mm and / or by less than 20mm.

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According to a second aspect of the present disclosure, a redox flow battery comprising a flow frame as set out above is provided.

BRIEF DESCRIPTION OF THE DRAWINGS

In the following, embodiments of the present invention will be described as non-limiting examples with reference to the accompanying drawings in which:

5 FIG.1 shows the major components of a redox flow battery;

FIG.2 shows a battery stack of a redox flow battery;

FIG.3 shows the components of a battery stack of a redox flow battery;

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FIG.4 shows a flow frame for a redox flow battery according to an embodiment of the present invention; and

FIG.5 shows an expanded view of flow channels and vanes of a flow frame

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according to an embodiment of the present invention.

DETAILED DESCRIPTION

FIG.1 shows the major components of a redox flow battery. As shown in FIG.1, the
20 redox flow battery 10 comprises a battery stack 12, electrolyte tanks 14 and electrical components 16.

The electrolyte tanks 14 hold a positive electrolyte and a negative electrolyte. In use, the positive electrolyte is pumped through a permeable positive electrode within the
25 battery stack and the negative electrolyte is pumped through a permeable negative electrode within the battery stack. The permeable positive electrode and the permeable negative electrode are separated by a membrane. This process generates an electrical current between the electrodes when the battery is being discharged, or generates charged ions in the electrolytes when the battery is being charged.

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The electrical components 16 may comprise a rectifier and inverter if the redox flow battery is used with alternating current. The electrical components may also comprise

control circuitry for pumps which pump the positive and negative electrolytes through the battery stack 12.

FIG.2 shows a battery stack of a redox flow battery. As shown in FIG.2, the battery stack 12 comprises a plurality of components 20 which are planar layers arranged between two end plates 22. The battery stack 12 is held together by a set of bolts 24.

FIG.3 shows the components of the battery stack of a redox flow battery. The battery stack 12 comprises an end plate 22. An insulator 30 is arranged adjacent to the end plate 22. A current collector 32 is arranged adjacent to the insulator 30. The current collector 34 is in contact with a bi-polar plate 34. A flow frame 40 having a rectangular cavity is adjacent to the current collector 32 and the bi-polar plate is sized to be accommodated in the rectangular cavity of the flow frame 40. A felt electrode 36 is also sized to be accommodated in the rectangular cavity of the flow frame 40. A gasket 38 having a rectangular cavity corresponding to the felt electrode 36 is located adjacent to the flow frame 40. An ion exchange membrane 42 is located over the cavity in the gasket 38. On the opposing side of the ion exchange membrane 42, corresponding components are arranged such that a second felt electrode opposes felt electrode 36 shown in FIG.3 on the opposing side of the membrane 42. Similarly, a second flow frame, a second bi-polar plate and a second current collector are located on the opposing side of the membrane to the components shown in FIG.3. Finally, a second insulator and a second end plate complete the battery stack.

The present disclosure relates to the configuration of the flow frame of a redox flow battery. The flow frame is configured for uniform flow distribution for the battery stack. The design of flow frame is important for the uniform distribution of electrolyte. Non-uniform distribution of the electrolyte results to reduction in electrode utilization and formation of dead zones (i.e. areas with less supply of fresh electrolyte). These effects are most critical during charging, as they could trigger elevated gas evolution and corrosive degradation of the bi-polar plates.

FIG.4 shows a flow frame for a redox flow battery according to an embodiment of the present invention. As shown in FIG.4, the flow frame 40 is rectangular and forms a cavity 102. An inlet 110 is located in the corner of the flow frame 40. A plurality of

supply channels 112 run from the inlet to a plurality of supply channel openings arranged on a supply side of the rectangular cavity 102. A plurality of vanes 116 are arranged in two rows on the supply side of the rectangular cavity 102. As shown in FIG.4, the upper side of the rectangular cavity is referred to as the supply side and lower side of the rectangular cavity is referred to as the discharge side.

An outlet 120 is located in a corner of the flow frame 40 adjacent to the discharge side of the rectangular cavity 102. A plurality of discharge channels 122 run from the outlet 120 to a plurality of discharge channel openings 124 located on the discharge side of the rectangular cavity 102. A plurality of vanes 126 are arranged in two rows on the discharge side of the rectangular cavity 102.

The flow frame 40 is formed from compressible thermoplastic material developed by injection molding or non-compressible plastic material. The flow frame 40 has provision for the gasket for sealing and has the rectangular cavity is configured to accommodate the porous electrode and bi-polar plate.

A divider 130 runs between the supply side and the discharge side of the rectangular cavity 102. The divider 130 divides the rectangular cavity 102 into two sub-cavities. The divider 130 and the sides of the rectangular cavity 102 which run parallel to the divider 130 are provided with protrusions 140. As shown in FIG.4, the protractions are triangular in this embodiment.

When the battery stack is assembled, the porous felt electrode occupies the rectangular cavity 102 in the flow frame 40. Since the rectangular cavity 102 is divided into two sub-cavities by the divider 140, the porous felt electrode is formed as two parts. The protrusions 130 provided on the sides of the divider 140 and the sides of the rectangular cavity support the porous felt electrode during assembly of the battery stack. Having the divider 140 on the flow frame separates the cell into two cells hydraulically whereas electrically they are connected with the same bi-polar plate. This will make the use for porous felt electrode in two parts with easy handling and enhancing the uniform flow.

In use, the electrolyte is input into the inlet 110 and flows through the supply channels 112 to the supply channel openings 114. The electrolyte then flows past the vanes 116 and into the porous electrode which occupies the rectangular cavity 102. The electrolyte exits the porous electrode at the discharge side of the rectangular cavity 102 and flows past the vanes 126 and into the discharge channel openings 124. The electrolyte then flows through the discharge channels 122 to the outlet 120 and exits the flow frame 40 through the outlet 120.

The provision of multiple supply channels 114 to supply channel openings 116 distributed across the supply side of the rectangular cavity 102 provides an even distribution of electrolyte flow across the porous electrode occupying the rectangular cavity 102. The provision of vanes 116 further provides for uniform electrode flow across the porous electrode occupying the rectangular cavity 102. The divider 130 acts to divide the hydraulic circuit within the cell which provides improved flow distribution and reduces any zones with stagnant flow. The provision of the vanes 126 on the discharge side of the rectangular cavity 102 and the distribution of the discharge channel openings 124 across the discharge side of the rectangular cavity 102 further provide for uniform electrolyte flow.

As described above, the flow frame 40 is provided with numerous design features which provide uniform electrolyte flow. These features can reduce the various problems arising from the non-uniform flow distribution such as local overcharging of the electrolyte, formation of dead zones, gas formation, hot spots and performance degradation of the battery stack.

The rectangular cavity 102 is sized such that the length (labelled X in FIG.4) of the rectangular cavity 102 is at least twice a width (labelled Y in FIG.4) of the rectangular cavity 102. Thus, a length (X) of the rectangular cavity corresponding to a length of the supply side and the discharge side is at least twice a width (Y) of the rectangular cavity corresponding to a separation of the supply side from the discharge side. Configuring the rectangular cavity 102 in this way reduces the pressure losses across the cell and therefore minimizes pump losses. This in turn increases the efficiency of the redox flow battery.

FIG.5 shows an expanded view of flow channels and vanes of a flow frame according to an embodiment of the present invention. The view shown in FIG.5 shows the supply channels 112, the supply channel openings 114 and the vanes on the supply side of the rectangular cavity. It will be appreciated that the arrangement and configuration of the discharge channels, the discharge channel openings and the vanes on the discharge side of the rectangular cavity is analogous to the arrangement and configuration of the supply side of the rectangular cavity therefore the descriptions of the features of the supply side also apply to the discharge side.

As shown in FIG.5, the supply channels 112 run parallel to the top of the flow frame and then turn through a 90-degree angle and meet the supply side of the rectangular cavity to form the supply channel openings 114. Each of the supply channels 112 runs separately to a respective one of the supply channel openings 114.

The supply channels 112 are formed as grooves in the surface of the flow frame 40. The supply channels are covered by the gasket 38 (shown in FIG.3) which forms a top surface of the supply channels when the battery stack is assembled. The supply channels 112 have a depth of 1mm to 3mm and a width of 1mm to 3mm. The vanes 116 are formed as protrusions which extend upwards from a narrowed part of the flow frame 40. As shown in FIG.5, the vanes 116 are longer in the direction parallel to the supply side of the rectangular cavity than in the direction perpendicular to the supply side of the rectangular cavity and have rounded corners. The vanes 116 have a length (in the direction parallel to the supply side of the rectangular cavity) of 5mm to 20mm, a breadth (in the direction perpendicular to the supply side of the rectangular cavity) of 2mm to 8mm, and a height (in the direction out of the plane of the flow frame) of 1mm to 6mm. The vanes 116 are arranged in two rows in an offset manner such a vane in the first row is located directly in front of each of the supply channel openings 114, and a vane in the second row is located directly in front of the gaps between vanes in the first row.

It has been found that having a double layered arrangement of the vanes 116 increases the flow resistance thereby minimizing the current leakage or shunt losses ultimately resulting in better columbic efficiency.

In the embodiment described above, there is a single divider 130 which divides the rectangular cavity into two sub-cavities. Depending on the dimensions of the flow frame, multiple dividers each running between the supply side and the discharge side of the rectangular cavity may be provided.

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The divider 130 provides additional support to bipolar plate and also aids in preventing the bipolar plate from tearing and breaking due to buckling in the event of using thin bipolar plates. The provision of the divider also provides a higher possibility of uniform electrolyte distribution as it divides cavity into separate zones (left and right), reducing the chance of unutilized portions of the electrode.

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The protrusions 140 provided on the divider 130 and the sides of the rectangular cavity may have a triangular shape as shown in FIG.4. Alternative configurations such as rectangular shapes may also be used. The protrusions may extend from the sides of the rectangular cavity and from the divider by between 5mm and 20mm.

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The protrusions act as hooks to prevent the fall of porous electrode during the assembly of cell/stack avoiding need of any sticky tape, glue or external holders. The thickness of the spikes or notches is kept smaller than the compressed electrode, so that the flow of electrolyte will not be disturbed along the edge.

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The configuration of the flow frame described above was been optimized using flow simulation and ensures uniform distribution of electrolyte along the cross section.

Embodiments of the present invention may have the following advantages:

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1. Flow distribution is excellent, resulting in stable and very high efficiency (>85%) even at low flow stoichiometry.

2. Pressure drop along the flow manifolds and channel is very low.

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3. Compact design with overall size of stack only 20% larger than active area, resulting in maximum power density.

4. Protrusions holding the porous electrode tightly and preventing from falling during assembly of battery stack. This supports in stack production.

5. Active zone is divided into two or more parts without compromising the flow rate and electrical conductivity. This will reduce the chances of forming localized stagnant spots and ensures smooth liquid pass through the electrode.

6. Shunt current losses are reduced due to long and narrow channels and double rows of islands provided by the vanes.

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Whilst the foregoing description has described exemplary embodiments, it will be understood by those skilled in the art that many variations of the embodiments can be made within the scope and spirit of the present invention.

CLAIMS

1. A flow frame for a redox flow battery, the flow frame forming a rectangular cavity configured to receive at least one porous electrode, the flow frame comprising:
 - an inlet for receiving an electrolyte liquid;
 - a plurality of supply channels coupling the inlet to a plurality of supply channel openings arranged along a supply side of rectangular cavity;
 - an outlet for discharging the electrolyte liquid;
 - a plurality of discharge channels coupling the outlet to a plurality of discharge channel openings arranged along a discharge side of the rectangular cavity, the discharge side of the rectangular cavity being opposite the supply side; and
 - a divider running from the supply side of the rectangular cavity to the discharge side of the rectangular cavity which divides the rectangular cavity into sub-cavities, wherein a length of the rectangular cavity corresponding to a length of the supply side and the discharge side is at least twice a width of the rectangular cavity corresponding to a separation of the supply side from the discharge side.
2. A flow frame according to claim 1, further comprising a plurality of vanes provided in front of the supply channel openings and / or the discharge channel openings.
3. A flow frame according to claim 2, wherein the vanes are provided in two rows in front of the of the supply channel openings and / or the discharge channel openings.
4. A flow frame according to claim 3, wherein the two rows of vanes are arranged in an offset manner.
5. A flow frame according to any one of claims 2 to 4 wherein the vanes have a length in a direction parallel to the supply side and the discharge side of the rectangular cavity which is greater than a width of the vanes in a direction perpendicular to the supply side and the discharge side of the rectangular cavity.
6. A flow frame according to claim 5, wherein the length of the vanes is at least 5mm and / or less than 20mm.

7. A flow frame according to claim 5 or claim 6, wherein the width of the vanes is at least 2mm and / or less than 8mm.
8. A flow frame according to any one of claims 2 to 7, wherein the vanes have a height of at least 1mm and less than 6mm.
9. A flow frame according to any preceding claim, wherein the discharge channels and / or the supply channels have a width of at least 1mm and / or less than 3mm.
10. A flow frame according to any preceding claim, wherein the discharge channels and / or the supply channels have a depth of at least 1mm and / or less than 3mm.
11. A flow frame according to any preceding claim, wherein each of the plurality of supply channels runs separately from the inlet to a respective supply channel opening of the plurality of supply channel openings.
12. A flow frame according to any preceding claim, wherein each of the plurality of discharge channels runs separately from a respective discharge channel opening of the plurality of discharge channel openings to the outlet.
13. A flow frame according to any preceding claim, wherein the flow frame is provided with a plurality of protrusions on sides of the rectangular cavity configured to engage with the at least one porous electrode.
14. A flow frame according to any preceding claim, wherein the flow frame is provided with a plurality of protrusions on the divider and / or sides of the rectangular cavity, the plurality of protrusions configured to engage with the at least one porous electrode.
15. A flow frame according to claim 13 or claim 14 wherein the protrusions are rectangular or triangular in shape.

16. A flow frame according to any one of claims 13 to 15, wherein the protrusions extend into the cavity by at least 5mm and / or by less than 20mm.
17. A redox flow battery comprising a flow frame according to any one of claims 1 to 16.