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# Peak power shaving using Vanadium Redox Flow Battery for large scale grid connected Solar PV power system

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# Motivation

- Large scale acceptability of Solar PV power plants in India.
- Integration energy storage with solar PV power system satisfies demand side management, peak load shaving and power system reliability.
- Vanadium Redox Flow Battery is a special type of energy storage chosen for large scale solar PV power system.
- The whole system is designed in MATLAB/Simulink environment and with two practical set of solar irradiance data.
- A power management algorithm is proposed for optimized penetration of Solar PV source, VRFB storage and the distribution grid depending on the load pattern, availability of solar PV source and VRFB State of Charge.

# Why VRFB ??

- Independent scalability of power and energy capacity;
  - → The power capacity of VRFB is determined by the size of its cell stack.
  - → The energy capacity is determined by the amount of positive and negatively charged electrolyte stored into its two tanks.

- The electrolyte contains the same metal ions of Vanadium at both sides of anode and cathode so that membrane degradation caused by cross contamination through the ion exchange membrane is avoided.

- VRFB offers the highest lifecycle among all other conventional battery storage systems.

- VRFB can operate over a wide range of power input/output and moreover VRFB can tolerate deep discharge without compromising battery lifetime unlike other conventional batteries.

# Comparative Analysis of VRFB with other conventional Batteries

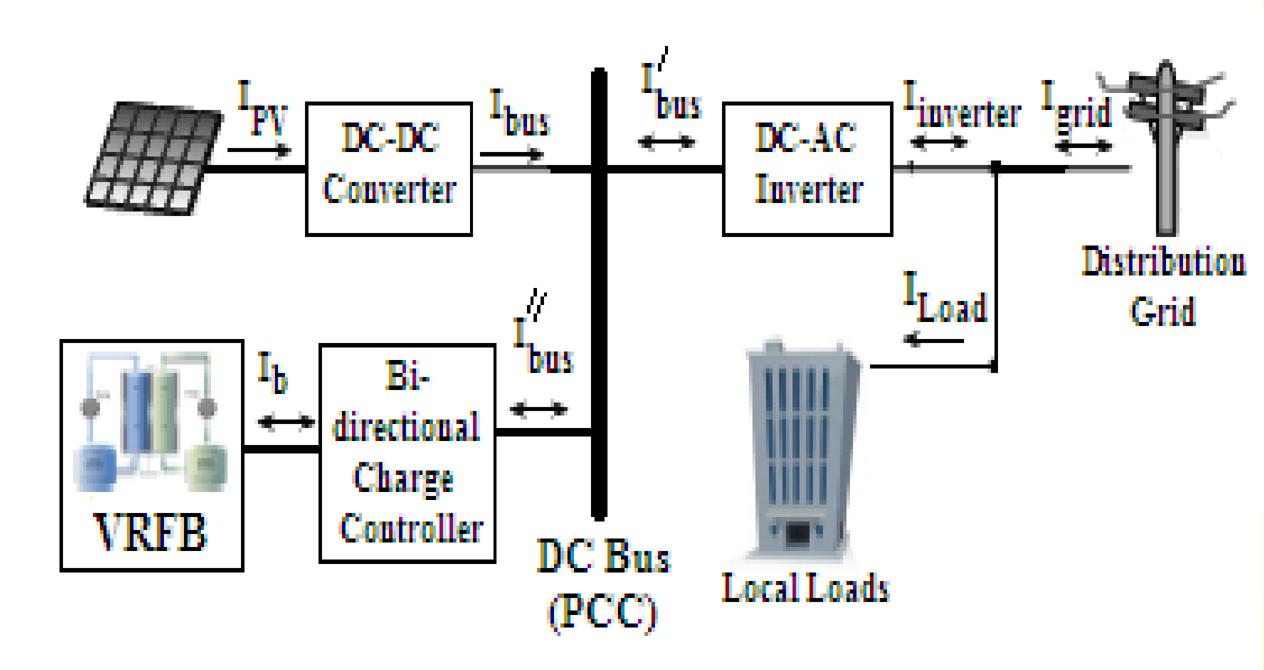
| Battery type | Life Cycle | Efficiency (DC-DC) | Nominal Cell Voltage |
|---|---|---|---|
| Lead Acid | 800 -1200 (50% DOD), 300 - 400 (90% DOD) | 75% - 80% | 2 - 2.4 Volts/Cell |
| Li-ion | 1000 – 1200 (50% DOD), 500 - 800 (90% DOD) | 80% - 90% | 3.6 – 3.7 Volts/Cell |
| Ni-Cd | 2000 (50% DOD), 1200 (90% DOD) | 70 – 80 % | 1 – 1.2 Volts/Cell |
| VRFB | 13000 (50% DOD), 8000 (95% DOD ) *The battery lifecycle can be made even longer by remixing the two side electrolyte after completion of one lifecycle | 75% - 85% | 1.25 – 1.6 Volts/Cell |

# Comparative Analysis among Redox Flow Batteries

| Redox Flow Batteries | Life Cycle | Cross Contamination | Efficiency (DC-DC) | Nominal Cell Voltage |
|---|---|---|---|---|
| FeCr | 4000 (90% DOD) | Suffers | 65% -75% | 1.1 – 1.4 Volts/Cell |
| ZnBr | 2500 (90% DOD) | Suffers | 70% - 80% | 1 – 1.2 Volts/Cell |
| VRFB | 8000 (95% DOD) | Not applicable | 75% - 85% | 1.2 - 1.6 Volts/Cell |

*** Data as per Report of *International Energy Storage Association***

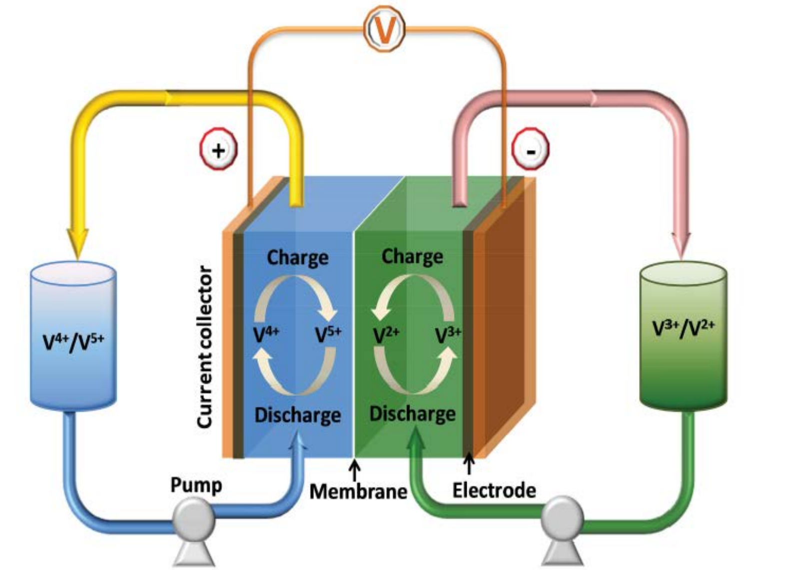
# Schematic of the proposed system

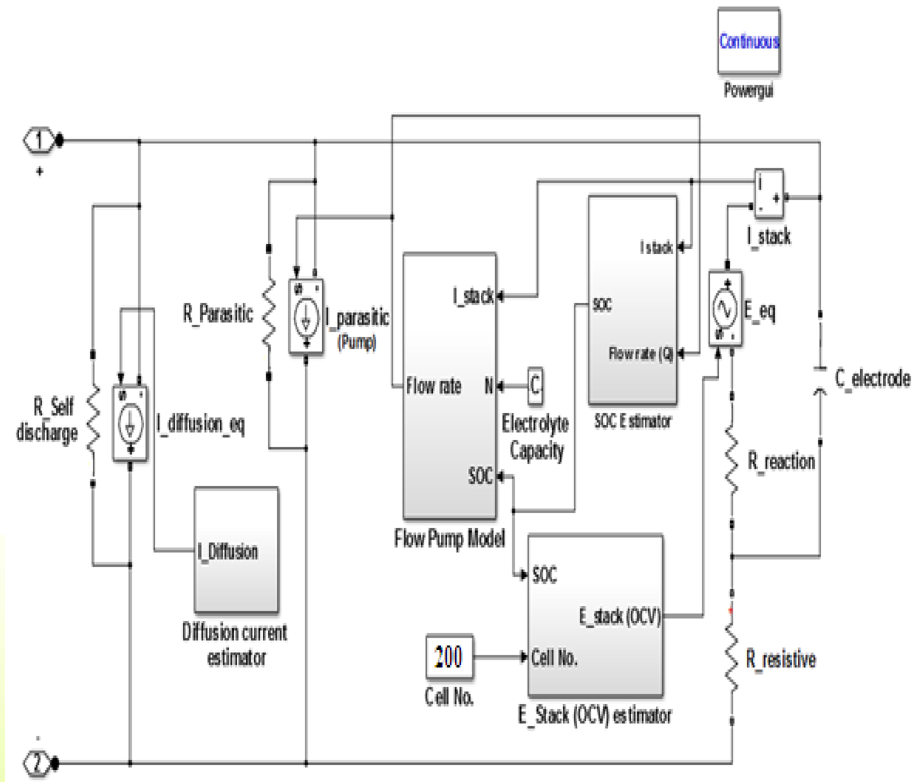


# Technical specification of major components for system design

| Parameter | Technical specification of major components for system design | | |
|---|---|---|---|
| | Solar PV Array | VRFB Storage | Load |
| Rated Power | 80 kWp | 10 kW 5 hr | 50kW (Peak Load) |
| Rated Voltage | $V_{mpp}$ = 1100 V | 320V | 415V (3-Ph) |

# MATLAB/Simulink Model of VRFB storage




$$V_{Cell} = V_{equilibrium} + \frac{2RT}{F} \ln\left(\frac{SOC}{1 - SOC}\right)$$

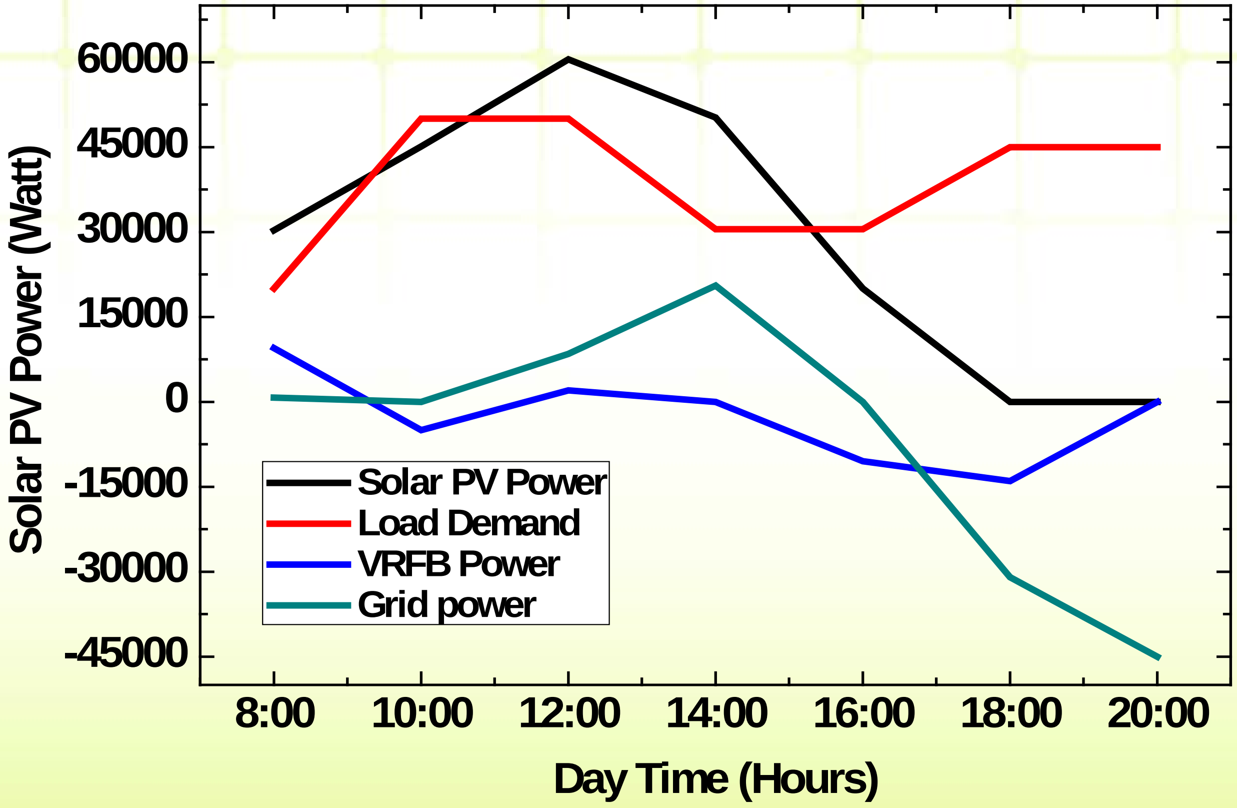
$$V_{Stack} = n \times V_{Cell}$$

$$V_{Termainal} = V_{Stack} - I_{Stack}(R_{reaction} + R_{resistive}) - \eta$$

# Proposed power management algorithm

- If $P_{PV} > P_{LOAD}$ and $90\% \geq VRFB_{SOC} \geq 10\%$,
- Then Solar PV supplies the load demand ($P_{LOAD}$) and VRFB is in charging mode.
- Else if, $P_{PV} > P_{LOAD}$ and $VRFB_{SOC} \geq 90\%$,
- Then PV will deliver excess power to the Grid after satisfying $P_{LOAD}$.
- If $P_{PV} < P_{LOAD}$ and $90\% \geq VRFB_{SOC} \geq 10\%$,
- Then $P_{PV} + P_{VRFB} \longrightarrow P_{LOAD}$
- Else if, $P_{PV} < P_{LOAD}$ and $VRFB_{SOC} \leq 10\%$,
- Then $P_{PV} + P_{GRID} \longrightarrow P_{LOAD}$
- If $P_{PV} << P_{LOAD}$ and $VRFB_{SOC} \geq 50\%$, (At night or cloudy weather)
- Then $P_{GRID} + P_{VRFB} \longrightarrow P_{LOAD}$
- Else if $P_{PV} << P_{LOAD}$ and $VRFB_{SOC} \leq 10\%$,
- Then $P_{GRID} \longrightarrow P_{LOAD}$

# Power management of the proposed Hybrid micro-grid



# Conclusion

- The proposed work has demonstrated the performance of VRFB storage for peak load shaving in a grid connected solar PV power system.

- An efficient power management algorithm is introduced in this work for optimized power sharing among the solar PV, VRFB storage, load and the distribution grid.

- The VRFB storage state of charge (SOC) is kept within an operating limit of 10% to 90% to avoid deep discharge and thus lengthening the battery storage lifetime.

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# *Thank you*