

FIG. 1A

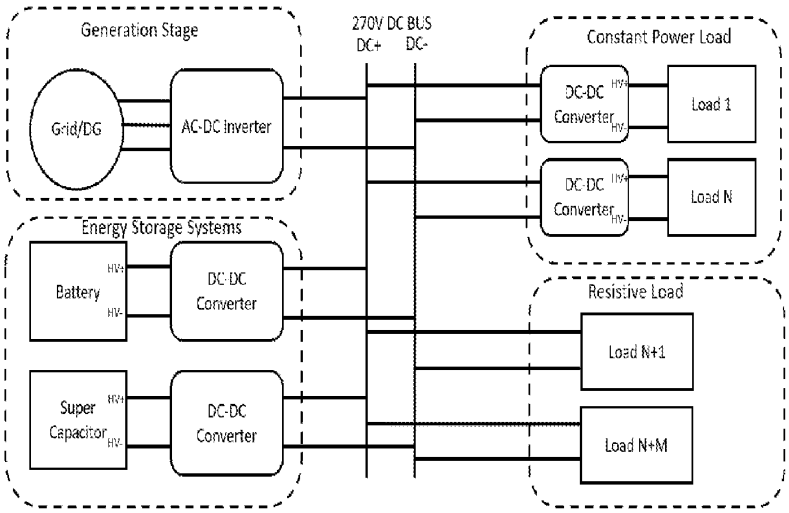


FIG. 1B

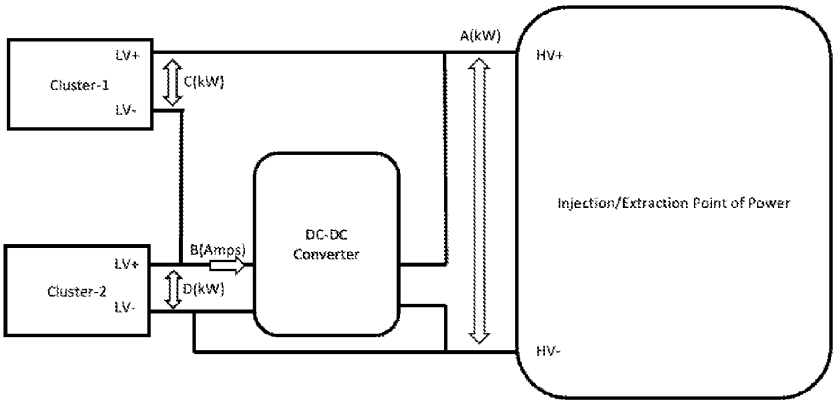


FIG. 2

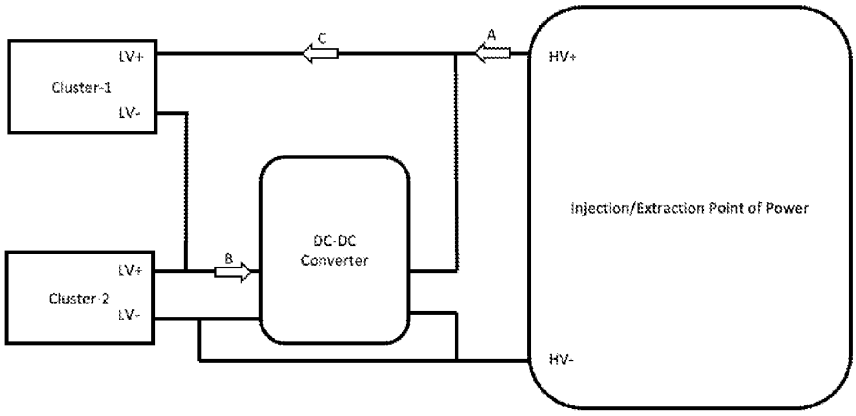

C
A
LV+
Cluster-1
LV-
HV+
Injection/Extraction Point of Power
DC-DC
Converter
B
LV+
Cluster-2
LV-
HV-

FIG. 3

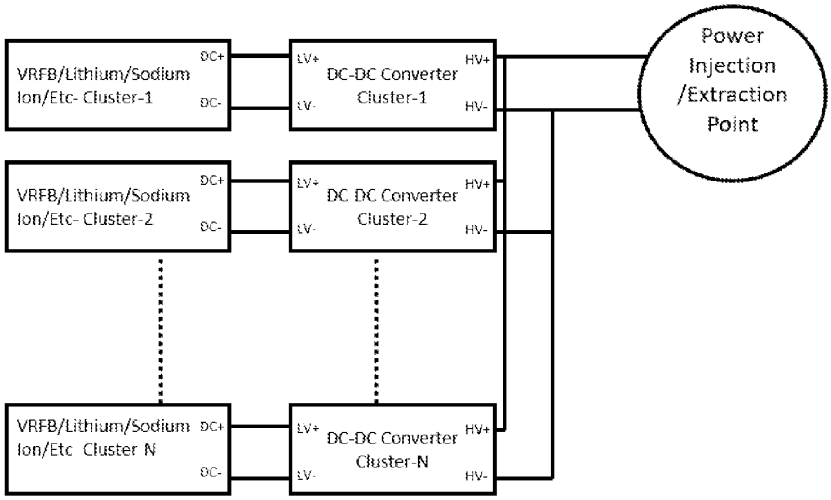

VRFB/Lithium/Sodium
Ion/Etc- Cluster-1
DC+
DC-
LV+
LV-
DC-DC Converter
Cluster-1
HV+
HV-
Power
Injection
/Extraction
Point
VRFB/Lithium/Sodium
Ion/Etc- Cluster-2
DC+
DC-
LV+
LV-
DC-DC Converter
Cluster-2
HV+
HV-
VRFB/Lithium/Sodium
Ion/Etc Cluster N
DC+
DC-
LV+
LV-
DC-DC Converter
Cluster-N
HV+
HV-

FIG. 4

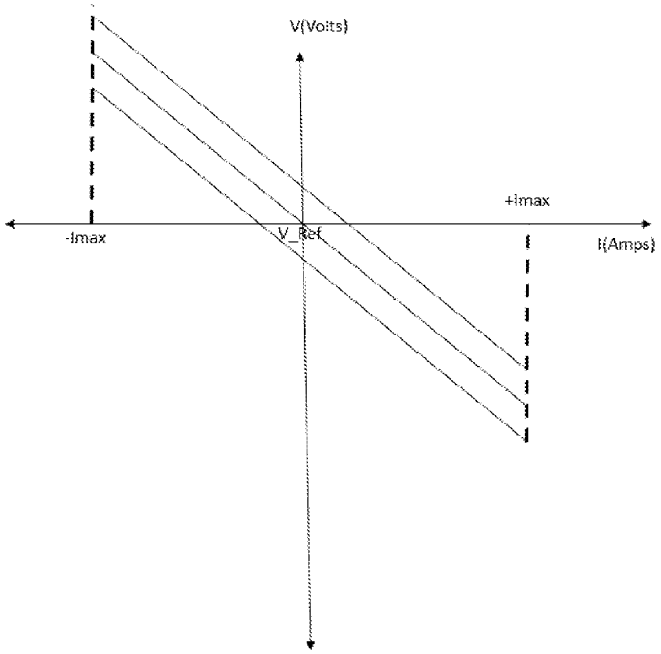


FIG. 5

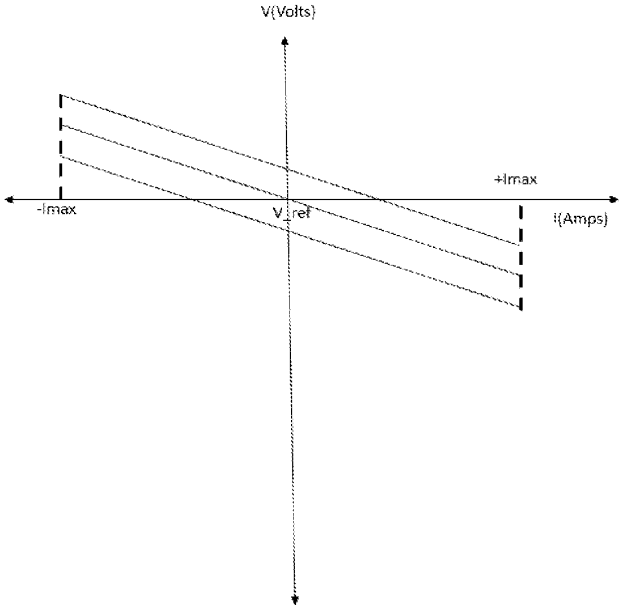


FIG. 6

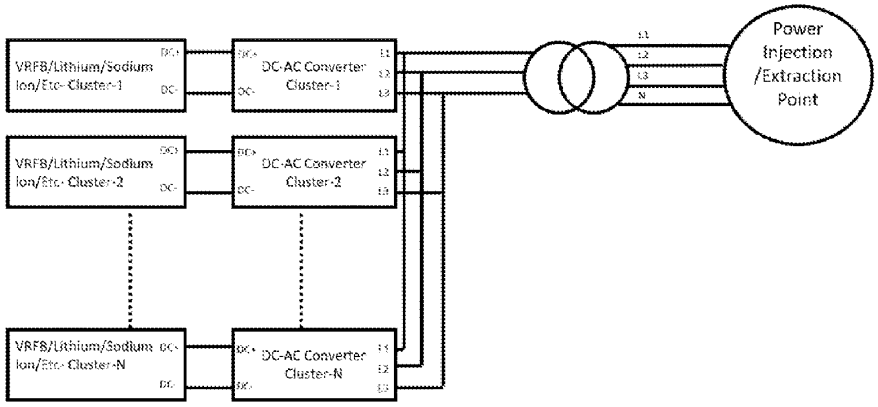

VRFB/Lithium/Sodium Ion/Etc- Cluster-1
DC+
DC-
DC-AC Converter Cluster-1
L1
L2
L3
N
VRFB/Lithium/Sodium Ion/Etc- Cluster-2
DC-AC Converter Cluster-2
VRFB/Lithium/Sodium Ion/Etc- Cluster-N
DC-AC Converter Cluster-N
Power Injection /Extraction Point

FIG. 7

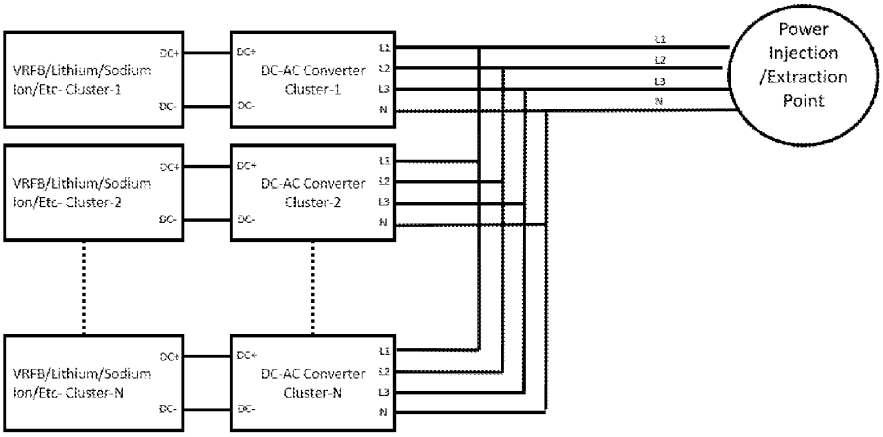

VRFB/Lithium/Sodium Ion/Etc- Cluster-1
DC+
DC-
DC-AC Converter Cluster-1
L1
L2
L3
N
VRFB/Lithium/Sodium Ion/Etc- Cluster-2
DC-AC Converter Cluster-2
VRFB/Lithium/Sodium Ion/Etc- Cluster-N
DC-AC Converter Cluster-N
Power Injection /Extraction Point

FIG. 8

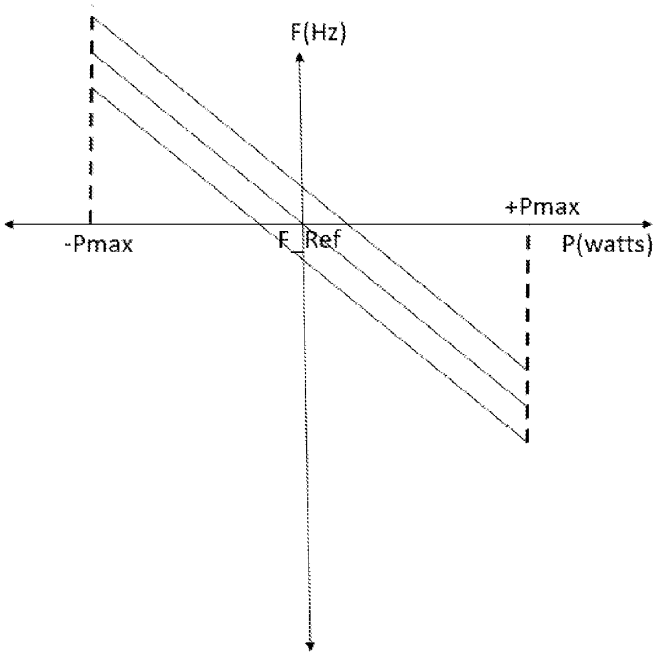


FIG. 9

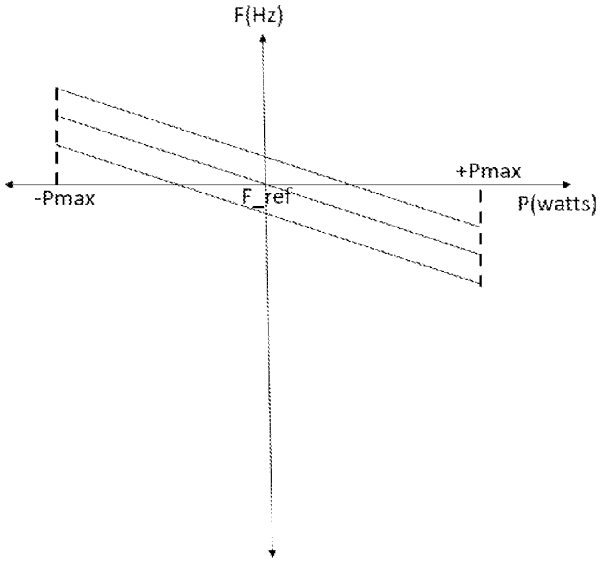


FIG. 10

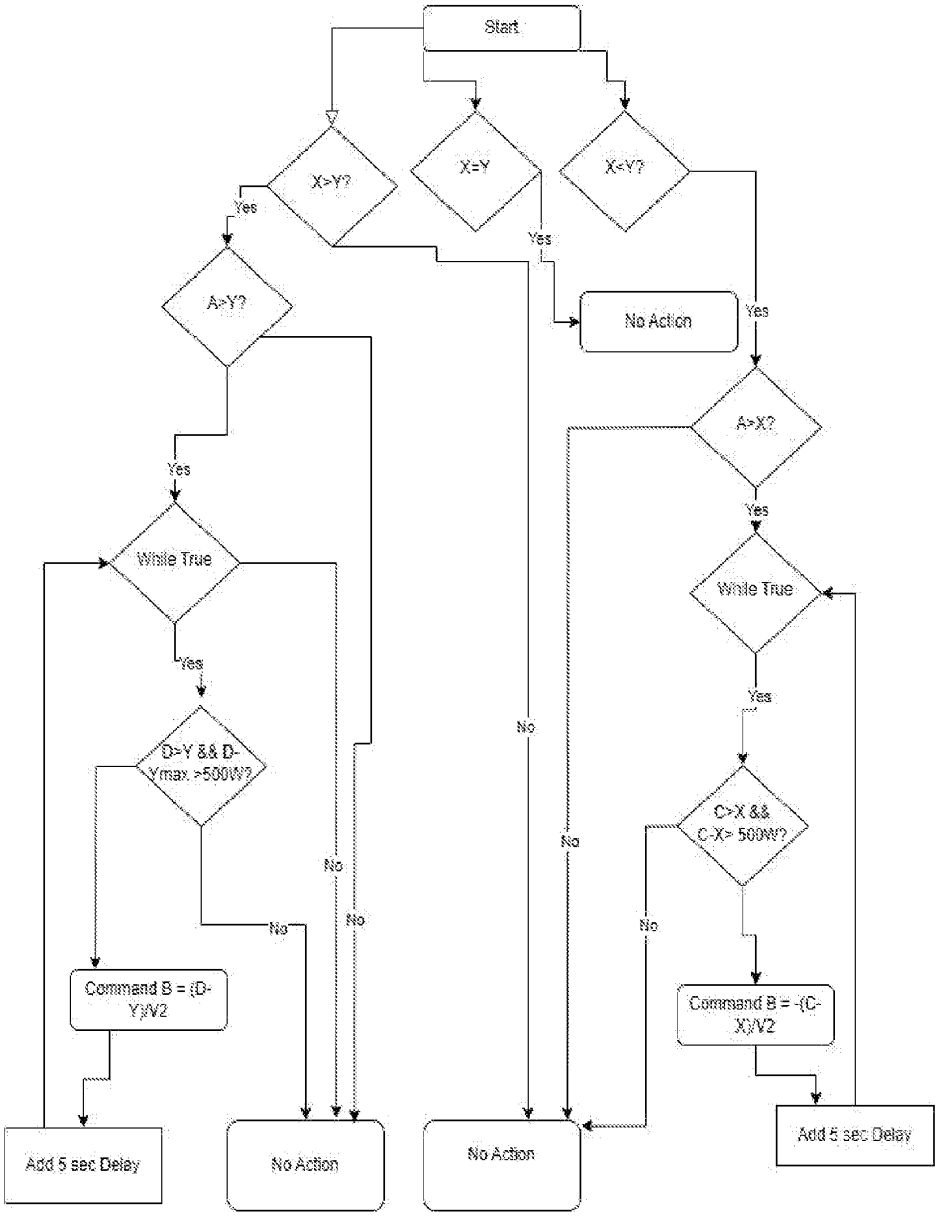

Start
X>Y?
X=Y
X<Y?
Yes
Yes
A>Y?
No Action
Yes
A>X?
Yes
Yes
While True
While True
Yes
Yes
D>Y && D-Ymax.>500W?
C>X && C-X> 500W?
No
No
No
No
No
Command B = (D-Y)/V2
Command B = -(C-X)/V2
Add 5 sec Delay
No Action
No Action
Add 5 sec Delay

FIG. 11A

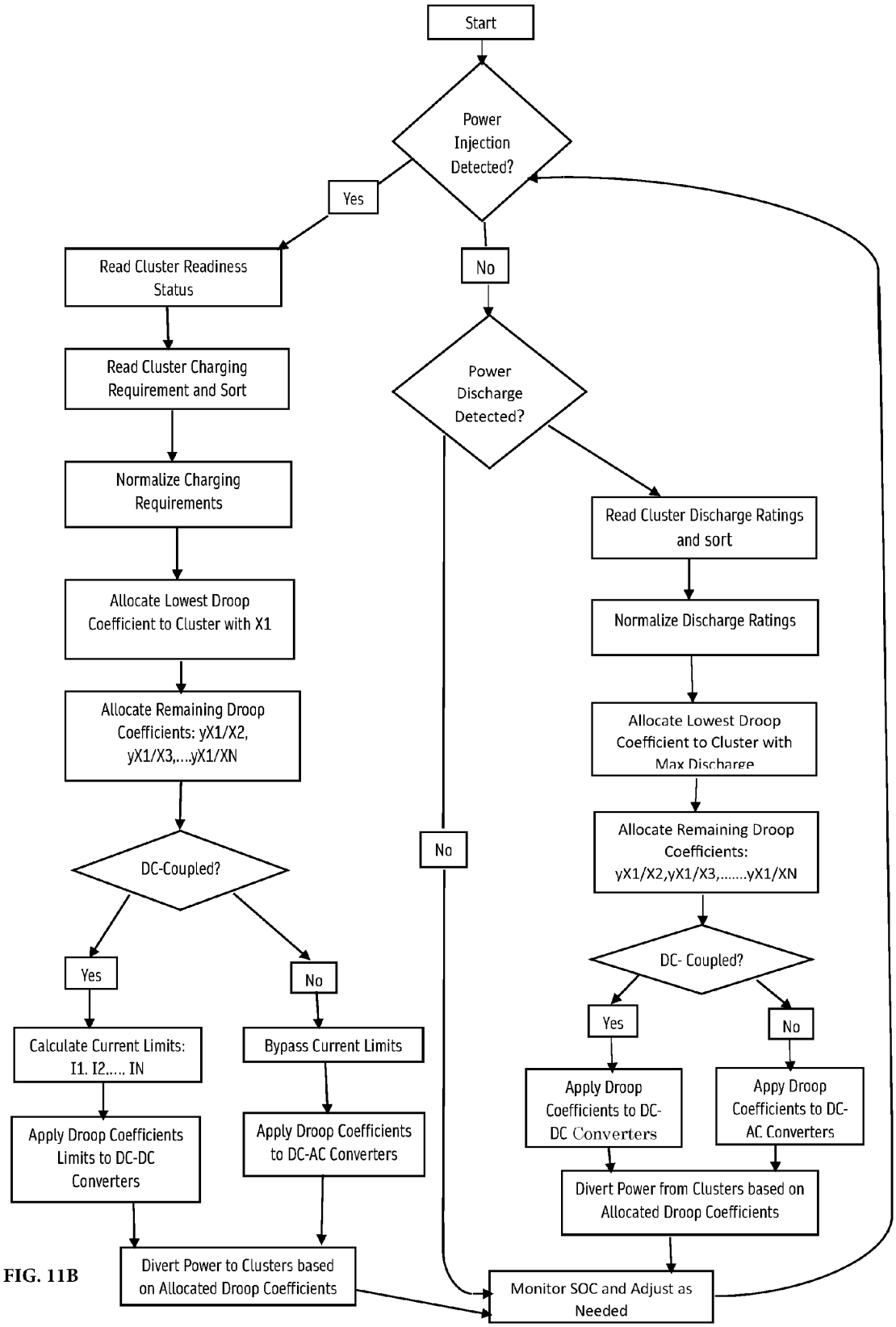

Start
Power Injection Detected?
Yes
No
Read Cluster Readiness Status
Read Cluster Charging Requirement and Sort
Normalize Charging Requirements
Allocate Lowest Droop Coefficient to Cluster with X1
Allocate Remaining Droop Coefficients: yX1/X2, yX1/X3,...yX1/XN
DC-Coupled?
Yes
No
Calculate Current Limits: I1, I2..., IN
Apply Droop Coefficients Limits to DC-DC Converters
Bypass Current Limits
Apply Droop Coefficients to DC-AC Converters
Divert Power to Clusters based on Allocated Droop Coefficients
Power Discharge Detected?
No
Read Cluster Discharge Ratings and sort
Normalize Discharge Ratings
Allocate Lowest Droop Coefficient to Cluster with Max Discharge
Allocate Remaining Droop Coefficients: yX1/X2,yX1/X3,.....yX1/XN
DC- Coupled?
Yes
No
Apply Droop Coefficients to DC-DC Converters
Appy Droop Coefficients to DC-AC Converters
Divert Power from Clusters based on Allocated Droop Coefficients
Monitor SOC and Adjust as Needed

FIG. 11B

If X >Y

- If A > Y: (Injection power is greater than cluster-2 Charging requirement
  - Current Command is calculated as follows
  - While True:
    - If D > Y && D-Y>500W (This value is adjusted based on the requirement of accuracy of protection from overcharge)
      - Command current = (D – Y)/(V2) (Positive number means DC-DC is commanded to take power from LV to HV side.)
      - Add 5 sec delay (for the current command to reach the desired set point.)
      - Loop again
- Else:
  - No Action

- If X < Y:
  - If A > X (Injection power is greater than cluster-1 Charging requirement)
    - Current Command B is calculated as follows
    - While True:
      - If C > X && C-X>500W (This value is tweaked based on the requirement of accuracy of protection from overcharge)
        - Command B current = -(C-X)/(V2) (Negative number means DC-DC is commanded to take power from HV to LV side.)
        - Add 5 sec delay (for the current command to reach the desired set point.)
        - Loop again
  - Else:
    - No Action
- If X=Y:
  - No Action

FIG. 12A

- When X > Y (Power demand of cluster 1 is greater than the cluster 2):
    - Check if A > Y: If the injection power is greater than the cluster-2 charging requirement.
        - If this condition is true, enter a loop where the current command is calculated as follows:
        - While True:
            - Check if D > Y and (D - Ymax) > 500W: This condition ensures that the difference between D and Y is large enough (greater than 500W) to trigger a protective action to avoid overcharging.
            - If the condition holds, Command B current = (D - Y) / V2: The current is calculated based on the difference between D and Y, divided by voltage V2. This will determine how much current should be taken from the LV side and transferred to the HV side.
            - Add a 5-second delay for the current command to reach the desired set point.
            - The loop continues to recheck above conditions.
    - If the condition does not hold no action is taken.

FIG. 12B

- When X < Y (Power demand of cluster 1 is less than the cluster 2):
    - Check if A > X: If the injection power is greater than cluster-1 charging requirement.
        - If this condition is true, enter a loop where the current command is calculated as follows:
        - While True:
            - Check if C > X and (C - X) > 500W: This condition ensures that if the difference between C and X is large (greater than 500W), to trigger a protective action to avoid overcharging.
            - Command B current = -(C - X) / V2: In this case, the current command will be negative, meaning that the DC-DC converter is instructed to take power from the HV side and send it to the LV side (opposite of the first scenario).
            - Again, add a 5-second delay for the current command to reach the desired set point.
            - The loop continues to recheck these conditions.
    - If the condition does not hold, no action is taken.
- When X = Y (Power demand of cluster 1 is equals to the cluster 2):
    - No action is taken when the power levels are equal, because there is no need for adjustment.

FIG. 12C