A Novel Method for Energy Transfer and Trading in Smart DC Microgrids

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***Abstract* - Energy transfer and Energy trading is the future of microgrids. Renewable energy sources that can be implemented in the home paved the way for prosumers. Using PV arrays, windmills, etc. the consumers are able to produce surplus energy. This surplus energy is underutilized in the existing microgrids. The surplus green energy can be utilized only through energy transfer. This paper put forwards a novel method for energy transfer and trading in Smart DC Microgrids.**

***keywords* - Energy transfer, Energy trade, PV arrays, DC microgrids**

I. Introduction

Electricity production across the globe is focusing on Green Energy, which is possible using renewable energy sources. The development in the field of renewable energy sources introduced PV arrays, Windmills, Tidal stream generators, etc. Further advancements in technology made the installation of PV arrays and windmills in homes. This made the consumers produce electricity on their own. The prosumers are able to produce excess energy which is usually unconsumed due to the limit in battery capacity. If we could use the excess unused energy efficiently, we could increase green energy production.
This can be made possible if we could share the excess energy produced with other consumers. Microgrids are capable of generating the energy requirement within the grid. Advancements in Microgrids could enable energy sharing within the microgrids. This paper introduces a novel method for energy transfer and trading in Smart DC Microgrids.

II. Microgrid

According to the US Department of Energy; A group of sources and loads are considered to be a microgrid if it satisfies the following criteria

- A clearly defined electrical boundary
- It includes a controller to control the DERs (Distributed Energy Resources) and loads to behave as a single controllable entity.
- The installed generation capacity is greater than the peak critical load.
- An active switch to connect and disconnect it from the distribution network to shift between the grid-connected and islanded mode

III. DC Microgrid

A microgrid that uses a DC bus network for interconnecting the distributed generators and loads in the system is called a DC microgrid. The operational voltages of these DC buses range from 350-400 V. High voltage gain DC-DC converters in DC-type microgrids increase the feasibility of connecting low voltage power sources like solar modules (typically 20-45V) by boosting them to the high voltage DC bus. DC-AC converters make the DC microgrid suit the AC loads.

1. Advantages of DC Microgrid

The DC microgrids have a number of advantages in various applications such as:

i. A DC system has no skin effect. The current will flow through the entire cable. This will reduce losses to transmitting power with fewer conductors.
ii. Grid synchronization, harmonics compensation, and reactive power control are not required for DC-based systems. Therefore, the operational complexity of the system is reduced.
iii. A DC microgrid provides a continuous power supply to the load during power outages and grid disturbances
iv. In a DC microgrid there is only one component to control, which is the DC power.

v. Increase the introduction of distributed PV units.

2. Existing DC Microgrid

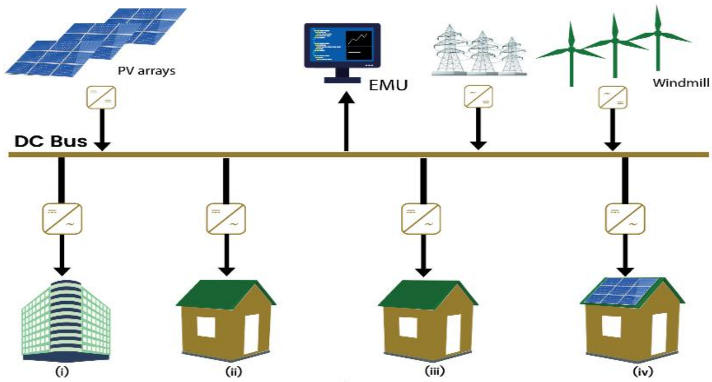

Figure 1
i,ii,iii - Consumer loads
iv - Prosumer loads

The DC microgrids which are existing now consist of a DC bus, power generators, Energy Management Unit, and loads. The DC bus distributes the power within the microgrid. DC-AC power converters are used to convert the DC supply to suit the AC loads. The PV arrays can be easily integrated with the DC bus for power generation. Apart from that, the supply from the power grid after converting using an AC-DC converter is fed to the DC bus. The energy can also be generated using the windmill installation within the microgrid. The produced energy is fed to the DC bus and the EMU controls the energy flow in the DC microgrid. Here consumers can consume energy without much complexity. But energy transfer or energy trade is not possible within this microgrid.

IV. Energy trade-enabled smart DC Microgrid

ET (Energy Trade) enabled Smart DC Microgrid enables the prosumer to sell the excess energy produced. Also, it enables Energy trading and energy transfer in the DC Microgrid. The detailed block diagram of the proposed system is given in Figure 2.

The generated power from the Microgrid is transmitted through the DC bus. In ET-enabled Smart Microgrid, we introduce another bus, which is the DC Energy Trade bus. The DC Energy trade bus play as the energy trade platform. That is, energy trade and energy transfer are enabled through the DC ET bus. The Prosumer can transfer the excess energy produced in his home to the DC ET bus. The Battey banks installed get charged using the excess energy produced. The DC ET bus and the BMS of the battery bank are connected to the SEMU (Smart Energy Management Unit), where the data is stored and the necessary control actions coordinated. SEMU records all the changes and energy flow in the DC ET bus also. By combining these data, and with a detailed analysis SEMU could perform the Energy Trade function. For that, the data collected by the SEMU is to be uploaded to a cloud-based system or to a local network, which can be accessed by the consumers.

In this proposed system, the generated energy in the microgrid is converted to a DC supply of a standardized value and fed to the DC bus. All the consumer loads are connected to the bus. A tariff is set by the energy distribution body for consuming the energy. As this DC microgrid is ET-enabled, the prosumers can sell the excess energy produced in their home. The excess energy produced by the prosumers is transmitted to the DC ET bus (DC Energy Trade bus) through an ET-SEM (Energy Trade enabled Smart Energy Meter). The ET-SEM records the energy transferred to the DC ET bus in units. The energy transferred is stored in the battery bank. The overall control of this microgrid is done by the Smart Energy Management Unit.

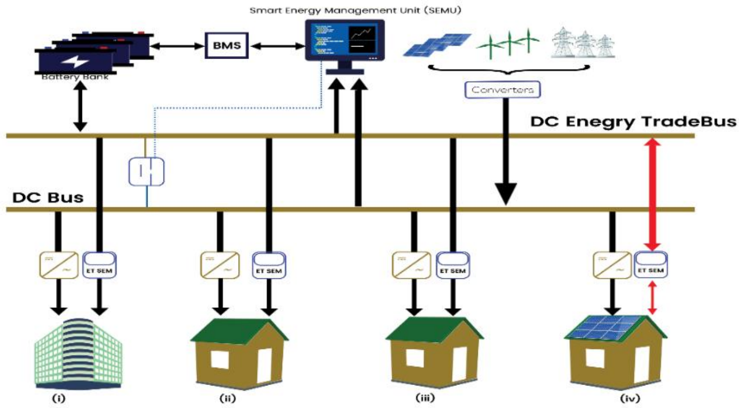

Figure 2
i,ii,iii – Consumer
iv – Prosumer

1. **Proposed System for Consumers**

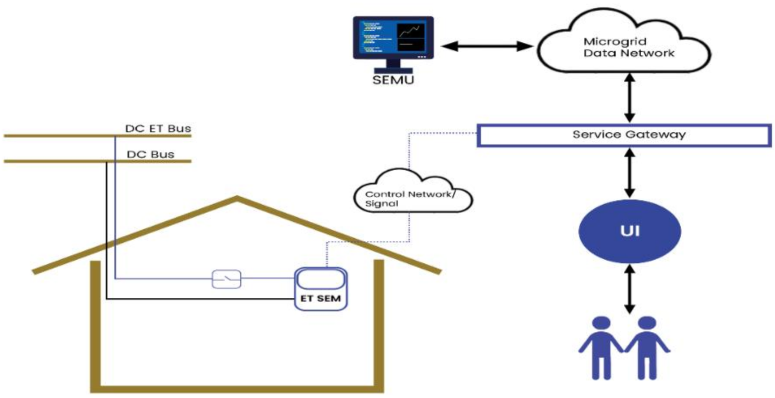

Figure 3: Consumer in ET enabled Smart DC Microgrid

Here the DC supply from the DC bus reaches the ET SEM and it is converted to AC and fed to the household loads (Figure 3). Here there is only consumer loads, so the ET SEM enables the purchasing of power. The user/consumer can see the amount of energy in the DC ET bus that can be purchased, through the User Interface. The user can select the number of units below the potential of the bus. The UI interacts with the service gateway for selecting the required amount of power and payment process. Once the payment is completed, the data reaches the SEMU through the Microgrid Data Network. The data is processed and the instruction from the SEMU reaches the ET SEM through the service gateway. The control signal reaches the ET SEM and turns ON the relay which is connected to the DC ET bus. The ET SEM records and analyses the energy consumed and when it reaches the limit, the relay will be automatically turned off.

2. **Proposed System for Prosumers**

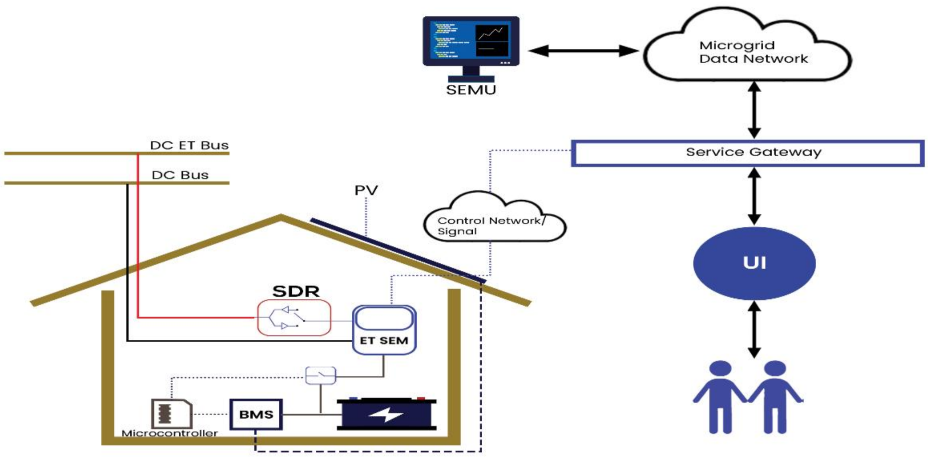

Figure 4: Prosumer in ET enabled Smart DC Microgrid

Here the prosumer is connected to the ET DC microgrid (Figure 4). Apart from the consumer, the prosumer will have a battery to store the energy produced by installing green energy sources. The energy produced is stored in the battery. The BMS analyses the stored energy in the battery. When the battery is fully charged, a signal from the BMS reaches the microcontroller, and it turns ON the relay to the ET SEM. Then the ET-SEM enables the SDR (Smart Directional Relay) to transmit the energy from the prosumer to the DC ET bus. When the battery level comes under 90% of the capacity, then another signal from the BMS reaches the microcontroller. Then the microcontroller turns off the relay and the ET SEM switches the SDR to the mean position.

For the prosumer to buy energy, the SDR can be put on to position 2 and it acts like a consumer in the ET-enabled DC microgrid. This enables the prosumer to sell and buy energy in the DC microgrid. The tariff of the prosumer can be calculated according to the consumption and energy exchange.

That is,

$$P^p = P^c - P^e$$

Where P^p is the number of units of payable power

P^c is the number of units of power consumed

P^e is the number of units of power transferred to the grid

The energy distribution body can lower the tariff rates to encourage the prosumers for the active power trade in the DC microgrid.

V. Conclusion

Energy transfer and energy trade within the microgrid could enhance the consumption of green energy and it can make a far-reaching impact on environmental issues. As the underutilized energy is also consumed, the efficiency of the DC microgrid increases. These ET-enabled Smart DC microgrids help to sustain energy and also help to avoid situations like blackouts. The microgrids have islanded mode and that provides safety to the power grid. The proposed system can wipe out the energy crisis issues and load shedding.

The energy trade encourages consumers to become prosumers as they can reduce their tariff rates by transferring the excess energy produced. This enhances green energy utilization and helps to attain self-sufficiency.

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