Fuzzy Logic Based Control Strategy for Load Sharing Between PV Systems for DC -DC Converters

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Abstract- DC micro grids have sources like solar energy plants, battery storage systems, and fuel cell power plants. DC-DC converters are utilized in every of those systems to interface them with DC bus of the microgrid. For economically optimized operation of microgrid, it's necessary to own an impression system facultative desired load sharing between the DC-DC converters. The answer delineated here is incorporation of DC-voltage droop characteristics in every device. But embedding droop characteristics within the converters ends up in forceful voltage variations on DC bus with varying loads. To deal with this drawback, an impression system is incorporated that maintains a continuing voltage on DC bus of microgrid by dominant the voltage axis intercept of droop characteristics. This paper describes the fuzzy control strategy of voltage droop characteristics as a possible answer to load sharing management drawback for multiple DC sources and extends to design and simulation of a 48V DC bus.

Keywords—Microgrid Topology, DC-DC converter, DC Load sharing.

I. INTRODUCTION

MICROGRID is proving to be a promising technology to realize reliable and economical power grid with incorporation of distributed generation as well as renewable sources like wind, solar, etc. DC microgrids have several interconnected sources in operation in parallel, supply power to the DC bus loads. Solar energy plants, battery storage systems area unit connected to DC bus via DC-DC converters [3]. Rather like the frequency droop characteristics of interconnected synchronous generators that modify desired load sharing, there's want of an impression system embedded within the DC-DC converters facultative load sharing between them. In analogy to the frequency droop characteristics employed in AC (alternating current) generators, a voltage droop characteristics is incorporated in DC generators for the cause [4]. To handle this drawback, an impression system is incorporated that maintains a relentless voltage on DC bus of microgrid by dominant the voltage axis intercept of droop characteristics. In doing thus, it lifts the voltage droop line thus on shift the in operation purpose towards the required DC bus voltage level. This paper describes modeling and simulation of the voltage droop characteristics as applied to DC-DC buck converters and demonstrates the load sharing management for a 48V DC bus. The factors resulting in the DC-DC buck device design are mentioned.

II. LOAD SHARING CONTROL

A. Voltage Droop Characteristics

Voltage droop characteristic for a DC supply is that the trend of definite drop by output voltage for an explicit increase within the output power contributed by the supply. Fig. 1 shows schematic illustration of droop characteristics of two sources which may be mathematically generalized as,

$$V_1 = -m_1 P_1 + V_{NL} \quad (1)$$

$$V_2 = -m_2 P_2 + V_{NL} \quad (2)$$

Where,

m_1 , m_2 are the slopes of the droop lines of the two sources.

V_{NL} is no load voltage of the sources (voltage axis intercept of droop characteristics).

V_1, V_2 are terminal voltages the two sources.

B. Load Sharing

Consider the two DC sources having droop characteristics mentioned above (eqn.1, eqn.2). If P_{LOAD} is the net system load P_1 and P_2 is the power contributed by each individual DC source,

$P_1 + P_2 = P_{LOAD}$ (3)

Terminal voltage of two sources connected to the same DC bus has to be same with the assumption of zero connecting line resistance.

$V_1 = V_2$ (4)

From equation eqn. 1, eqn. 2 and eqn. 4,

$-m_1P_1 + V_{NL} = -m_2P_2 + V_{NL}$ (5)

Equation eqn. 3 and eqn. 4 is a set of two simultaneous equations solution to which is stated as follows:

$P_1 = P_{LOAD} * \frac{m_2}{(m_1+m_2)}$ (6)

$P_2 = P_{LOAD} * \frac{m_1}{(m_1+m_2)}$ (7)

From eqn.6 and eqn.7,

$\frac{P_1}{P_2} = \frac{m_2}{m_1}$ (8)

From eqn.8, it can be seen that the load sharing between two DC sources is inversely proportional to the slopes of their own voltage droop characteristic.

C. Effect of internal resistance

Internal resistance of each DC supply imposes its own voltage droop characteristics owing to the voltage Drop across itself. The changed voltage droop characteristics will expressed as,

$V_1 = -m_1P_2 + V_{NL} - I_1R_1$ (9)

$V_2 = -m_2P_2 + V_{NL} - I_2R_2$ (10)

Where,

I_1 and I_2 are the respective load currents supplied by the DC sources;

R_1 and R_2 are the internal resistances of the DC sources;

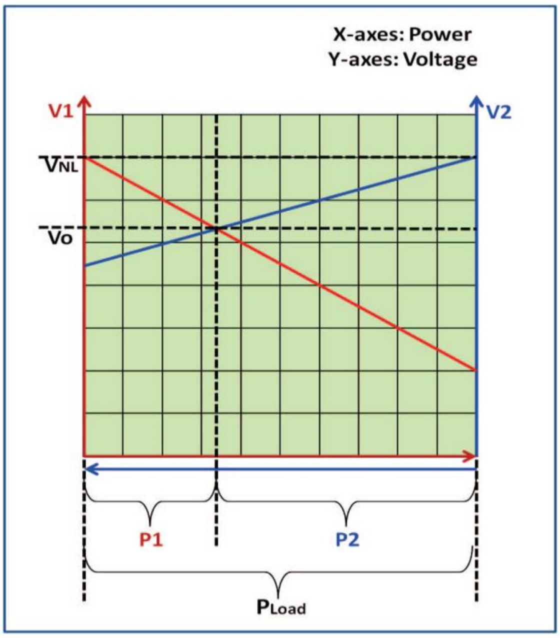


Fig. 1: Droop Characteristics of two DC sources/ DC-DC converters. V_o is the operating point voltage of load resulted from intersection of droop characteristics. P_1 and P_2 is the load shared by two sources out of total system load of P_{LOAD}.

Due to amendment in effective slope of droop characteristics due to internal resistance of sources, the load sharing between the sources is additionally modified in proportion to the new effective slopes. The amendment within the load sharing contributed by internal resistances will simply be stipendiary by dynamic the slopes of characteristics consequently.

III. CONSTANT VOLTAGE CONTROL (VOLTAGE AXIS INTERCEPT CONTROL)

Operating purpose voltage on the voltage droop characteristics is also set by the overall load on the system [5]. More the system load, lesser are going to be the operative purpose voltage of DC bus. As an answer to the current downside, voltage axis intercept (V_{NL}) of the droop characteristics is varied. This lifts up the droop characteristics and also the operative purpose voltage are often restored to the required worth. (Fig. 2) It is often shown that this doesn't modification the load sharing for the slopes area unit still maintained.

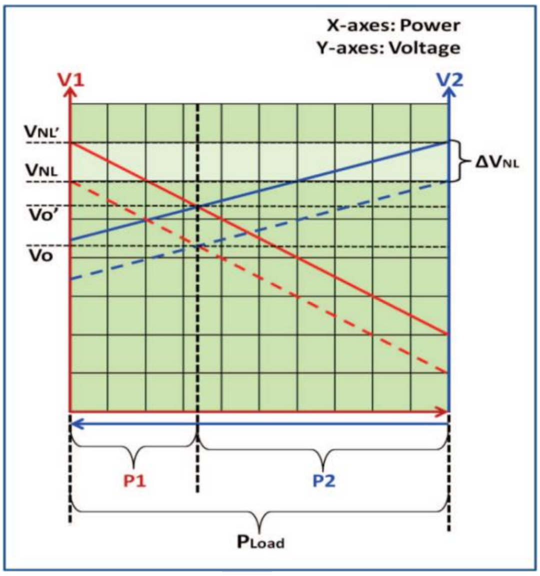


Fig. 2: Concept of constant voltage control: voltage axis intercept(V_{NL}) is varied to raise up the droop characteristics to increase the DC Bus in operation voltage (from V_0 to V_0'') without varied the previous load sharing. ΔV_{NL} is that the shift in the voltage axis intercepts.

IV. 48 VOLT DC BUS

This section describes design of a 48V constant DC bus by using voltage droop characteristic for load sharing control of two DC-DC buck converters. Fig.3 shows schematic representation of load sharing and Constant voltage management system takes DC bus voltage as feedback and uses a PID controller to manage voltage axis intercept. [2]

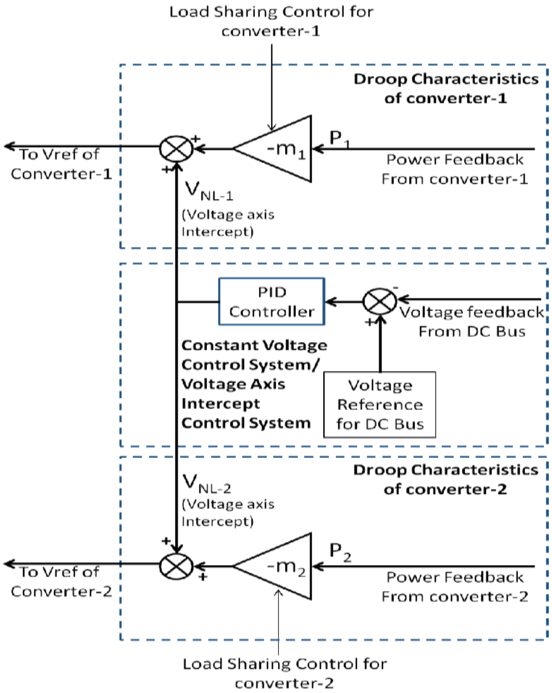


Fig. 3: Droop characteristics of sources and constant voltage control system controlling the voltage axis intercept.

A. Buck converter operation

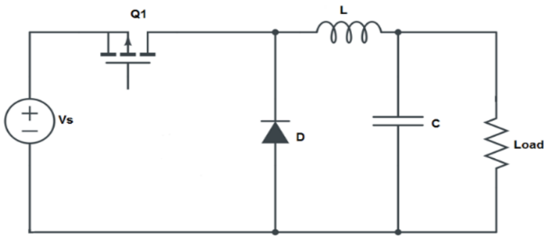


Fig.4: DC-DC buck converter

The system uses buck converter to step down the voltage to DC bus rating of 48 V. It consists of a MOSFET, an inductor, diode and a condenser to separate the output ripples. The device is operated in fixed frequency mode continuously. The device is intended to optimize the dimensions and efficiency by selecting acceptable switch frequency [6].The PID Controller drives the gate of Mosfet [2]. The crucial issue operative of any DC-DC device is that the worth of inductor and output filter condenser. The inductor worth is calculated therefore on operate it continuously in continuous mode; even for little load current and to attenuate this ripple content of the output. The operate of the output condenser is to filter the inductor current ripple and deliver a stable output voltage. It also has to make sure that load steps at the output may be supported before the regulator is ready to react. Following equations square measure accustomed notice the values of electrical device and condenser. [1]

$$L_{mean} = \frac{((V_{in(min)} - V_{out}) * D_{max})}{(\Delta I_L * f)} \tag{11}$$

$$C_{mean} = \frac{1}{(8 * f * \frac{\Delta V_{out}}{\Delta I_L} - R_c)} \tag{12}$$

Where,

V_{in} (min) =minimum input voltage

V_{out} =output voltage

ΔI_L=inductor ripple current

D_{max} =maximum duty cycle

R_C =Equivalent series resistance of capacity

Block Diagram

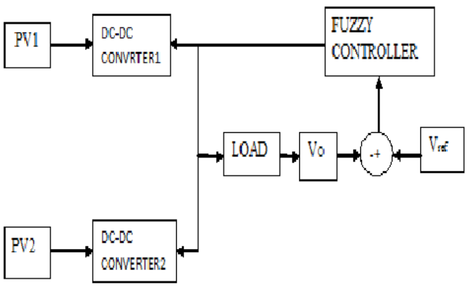


Fig. 5: Voltage droop characteristics for load sharing and voltage control system

Consider a 48V DC bus having two DC-DC converters operating in parallel. DC Bus has variable loads. Output voltage of DC-DC converters can be controlled by controlling duty cycle of the PWM waves. Therefore to embed droop characteristic in a DC-DC converter, a definite reduction in duty cycle is made with increase in power. Slopes of droop characteristics of converter-1 and converter-2 are set to be -1/50 and -1/100 respectively to achieve 1:2 load sharing ratio. Further the reference to the constant voltage control system is set to be 48V. The converters and voltage control systems (fig. 5) Response of the control system to load fluctuations is studied.

V. RESULTS

A. Load sharing without voltage axis intercept control

Converter-1 and converter-2 (with slopes -1/50 and -1/100 respectively) share power within the load sharing quantitative relation of 1:2. Abrupt changes within the load on DC bus shows transient fluctuations in power from converters. However, load sharing quantitative relation of 1:2 is maintained even once load changes. Here voltage management is absent i.e. the voltage axis intercept of droop characteristics is unbroken constant. This ends up in DC bus voltage showing a drop of 0.5V from 48V to 47.5V (fig.6).

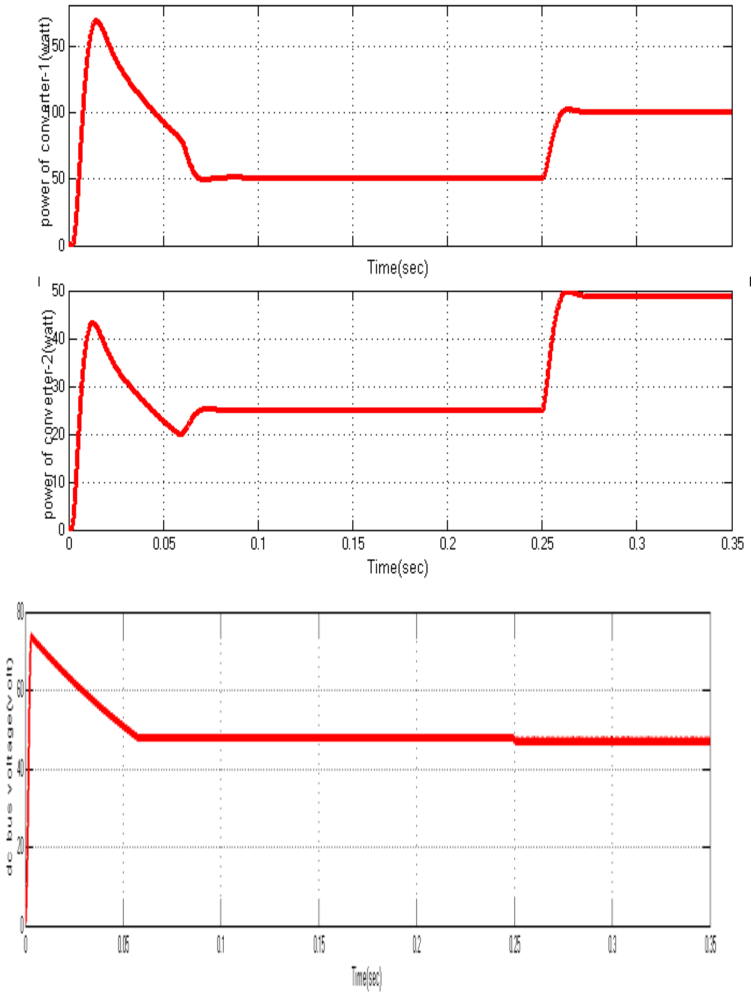


Fig. 6: Load sharing between converters and DC bus voltage WITHOUT constant voltage control system

B. Load sharing with voltage axis intercept control

Here voltage management is added in the system i.e. the voltage axis intercept of droop characteristics is currently varied by the PID controller. After sudden modification in load on DC bus, DC bus voltage shows transient damping oscillations; but eventually settles back to 48V. (Fig. 7) Load sharing ratio of 1:2 is maintained even after load changes.

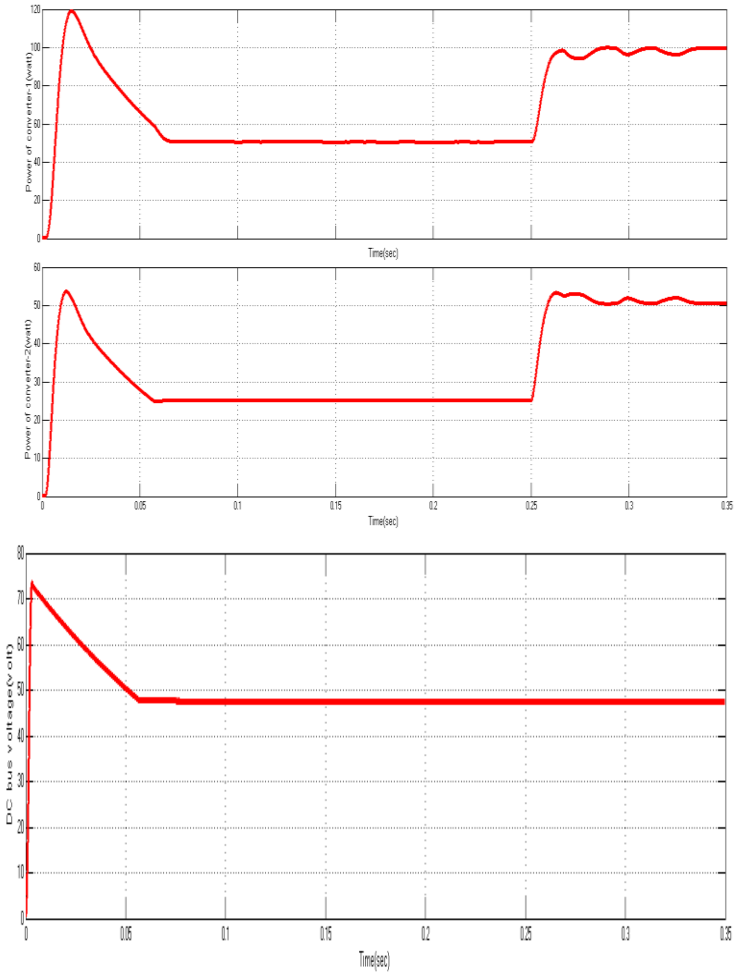
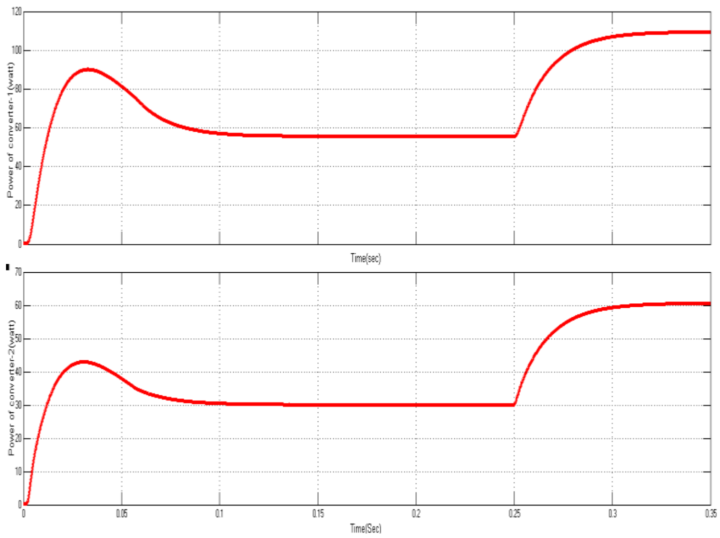


Fig. 7: Load sharing between two converters and DC bus voltage with constant voltage control/Voltage axis intercept control activated

C. Load sharing with FUZZY control

Here voltage control is value-added within the system i.e. the voltage axis intercept of droop characteristics is currently varied by the fuzzy controller. After sudden change in load on DC bus, DC bus voltage is constant which shows transient stability improvement; here steady state error is zero. Fuzzy controller has very quick response when compared to PID controller. Load sharing ratio of 1:2 is maintained even after load changes (Fig. 8).



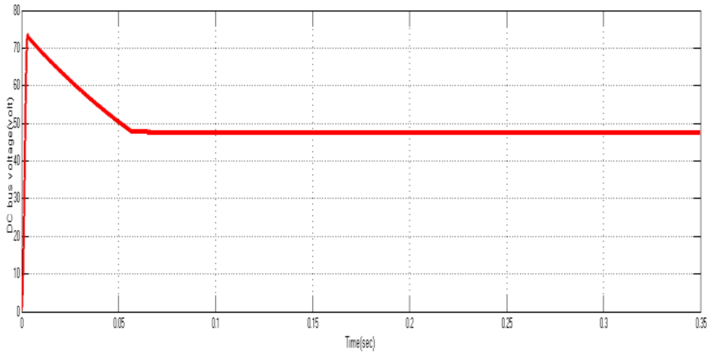


Fig. 8: Load sharing between two converters and DC bus voltage with constant voltage control/ fuzzy control activated.

Fig 9 shows steady state shift in the droop characteristics due to voltage axis intercept control system and the corresponding shift in the operating point from 47.5V to 48V.

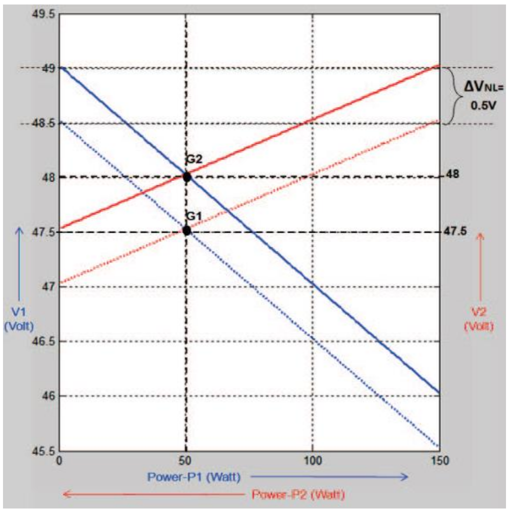


Fig 9: Steady state operating points: G1: Before voltage control; G2: after voltage control; Voltage intercept of the droop characteristic is shifted up by the control system by 0.5V; load sharing ratio is maintained to 1:2

VI. CONCLUSION

This paper presents a fuzzy control strategy for load sharing between multiple DC sources in a DC microgrid. Incorporation of droop characteristics in DC-DC converters enables desired load sharing. By controlling the voltage axis intercept of droop characteristics, constant DC Bus voltage can be maintained under any loading conditions. Transient response of control system improved by fuzzy control technique.

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