# High-Voltage Two Stage Smps using Constant Power Buck Converter

**Sung-Jun Park, Seong-Mi Park**

***Recently, empirical studies on power transfer using high-voltage DC, as in HVDC, Smart Grid, and direct current transmission & distribution, have been carried out lively. In the high-voltage DC transmission system, it is essential to adopt SMPS for power converter control using high-voltage DC input. Demand for high-voltage SMPS, however, has been low so far, and thus its development is inadequate. Particularly, in case of light load in low output SMPS using high-voltage input, it is difficult to achieve high efficiency due to transient switching losses. It is difficult to achieve high efficiency due to the switching transient loss especially at the light load in the low output SMPS using the high voltage input. It is difficult to achieve high efficiency due to the switching transient loss especially at the light load in the low output SMPS using the high voltage input. In this paper, we propose a new switching scheme for switching low power SMPS control from the point of view of current control. The proposed technique can have the excellent effect of efficiency increases under the condition of light load, compared with the existing PWM method. In addition, 40[W] SMPS for HVDC MMC was designed to test the validity of the proposed technique, and the validity was verified through simulation.***

***Keywords: HVDC MMC, high-voltage DC, smart grid, high-voltage SMPS***

## I. INTRODUCTION

The recent trend in power transmission system shows changes from AC transmission system to DC transmission system for the sake of efficient energy supply. Typical areas showing active research on DC transmission system are HVDC, Smart Grids, and direct-current transmission & distribution [1-3]. Such high-voltage DC transmission systems are mounted with the power converter, a semiconductor device, and thus, it is essential to install SMPS to control the power converter, using high-voltage DC input [4]. In particular, SMPS for HVDC MMC control power supply operates at a low operating rate at rated voltage due to wide input voltage fluctuation, resulting in increased product price and difficulty in controlling the product due to increase in rated current and high sensor sensitivity. Therefore, this paper proposes a two stage SMPS structure suitable for SMPS for control power supply for low output HVDC MMC operating in a wide input voltage fluctuation range and a new concept of switching from a constant energy control viewpoint for low power SMPS control. We propose a constant energy switching technique [5-6]. The proposed constant energy switching technique is characterized by the almost constant switching losses irrespective of the loads of SMPS. The switching technique can improve the reduction of efficiency caused by transient switching losses in case of light load in the existing current-control PWM method. In addition, 40[W] SMPS for 3000[V] HVDC MMC was designed to test the validity of the proposed technique, and the validity was verified through simulation.

## II. HIGH-VOLTAGE SMPS WITH A WIDE RANGE OF INPUT

### 2.1 Characteristics of SMPS for HVDC MMC

The HVDC system, a power converter for direct current transmission and distribution, which uses several MMCs in series, shows wide variations in MMC voltage, and the development of customized SMPS suitable to MMC control is urgently required for system protection. And high-voltage SMPS is considered to become essential in the future in keeping with the high voltage of MMC modules [7-9]. In the HVDC system, which is a power converter for DC transmission and distribution using several MMC in series, the fluctuation range of the MMC voltage is large, and customized SMPS suitable for MMC control for system protection is desperately required. The high-voltage of SMPS is also considered to be essential in the future [10-12].

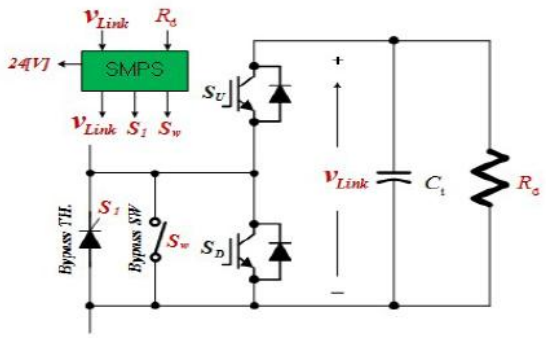


**Figure 1. Structure of MMC and role of SMPS**

Figure 1 shows the structure of half bridge-type MMC and the role of SMPS, an auxiliary power supply. Currently, the voltage of MMC tends to become high-voltage, and MMC consists of Rd, discharge resistance, a Bypass thyristor, and a mechanical switch. In addition, for the HDVC main controller, the voltage balancing control of every

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MMC connected in parallel is essential[13-15]. Thus, as for information on voltage of each MMC, it is desirable that the function of information delivery should be embedded in SMPS mounted on MMC. It is desirable to use a relatively low voltage sensing resistor for stable voltage detection. However, the resistance proves to be the main cause of reduced efficiency in SMPS. In fact, the efficiency of the whole system is generally reduced about 0.1-0.2 [%] due to MMC discharge resistance (Rd). Therefore, it is deemed that the hybridization of discharge resistance, the initial charge circuit, and the voltage sensing circuit will conduce to the increase of system efficiency. Further, an algorithm that generates signals for the bypass thyristor and switch in the event of MMC accident due to the main controller or communication interruption should be developed and embedded to prevent accident in advance.

### 2.2 The structure of high-voltage SMPS having a wide range of input

The SMPS for HVDC MMC driven by wide variations of high input voltage operates with low switching frequency due to high resistance strength, and with a low duty ratio due to a low voltage gain. In actuality, under the above conditions, it is difficult to design SMPS using the existing flyback converter. As shown in Figure 2, this paper proposes a conceptual diagram of a two-step power converter that uses a non-isolated step-down converter, which outputs constant voltage for efficient driving despite variations in input voltage, and an isolated flyback converter, which generates constant output voltage driven by constant input voltage.

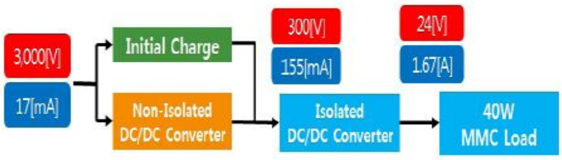


**Figure 2. The block diagram of proposed high-voltage SMPS**

In Figure 2, even though the input voltage is changed from 500 [V] to 3,000 [V], an output voltage of 300 [V] is used to maintain the constant voltage. The isolated flyback converter controls the output voltage to be the constant voltage of 300 [v] and 24 [V]. In addition, the initial charge circuit is operated only at the initial stage.

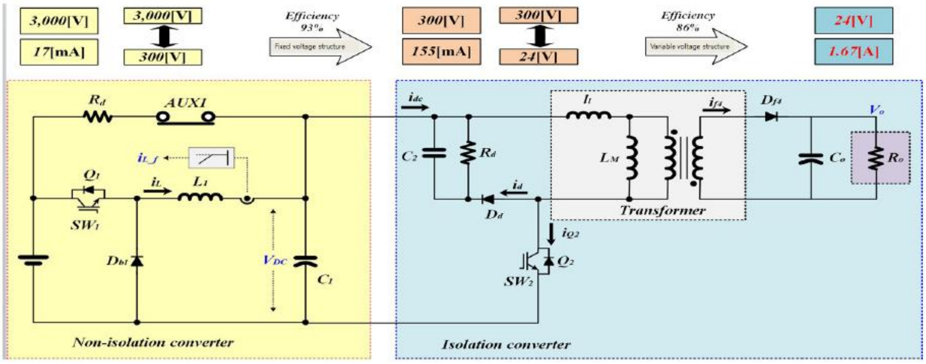


**Figure 3. The proposed high-voltage SMPS structure**

### 2.3 Switching system for constant energy output

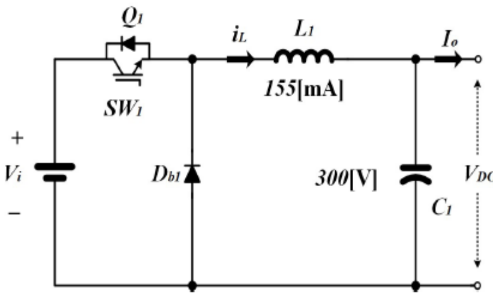


**Figure 4. Step-down converter**

Figure 4 shows the non-isolated step-down converter. In the continuous mode of this converter, the duty ratio (d) is 0.6-0.1 to maintain the output voltage of 300 [V] at the input voltage of 500 [V] - 3,000 [V], and the mean current of inductor to generate the output of about 46 [W] is about 155 [mA]. In case of control in the continuous mode, the conditions of the continuous mode are as follows:

$$L_1 \ge TV_{dc}\frac{1-d}{2I_0} \quad (1)$$

In case of calculation for the inductor using Equation (1), the value of inductance becomes very large. The converter comes to have a large time constant, and thus it is difficult to maintain stable output according to variations in input voltage or load. In addition, since the mean current of the inductor is small, there is the disadvantage that the transient loss of the switch device turns into a large total loss. Therefore, in this paper, the converter is operated in the discontinuous mode.

When the step-down converter of Figure 4 operates in the discontinuous mode, if the conduction time of the switch (Q1) is t1, energy transferred from the input side in case of one-time switch on-off is as follows:

$$\omega = \frac{1-d}{I_1}\int_0^{t_1} V_i(V_i - V_{DC})t\,dt_{[jole]} \quad (2)$$

If energy of Equation (2) is transferred with one-time switching motion, the output power is as follows:

$$P_0 = \eta_1 \omega f_{max}[W] \quad (3)$$

$f_{max}$ : switching frequency, $\eta_1$ : step-down converter efficiency

Supposing the input voltage and the output voltage are constant, the switch on-time to transfer constant energy from the input side is as


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follows from equation (2):

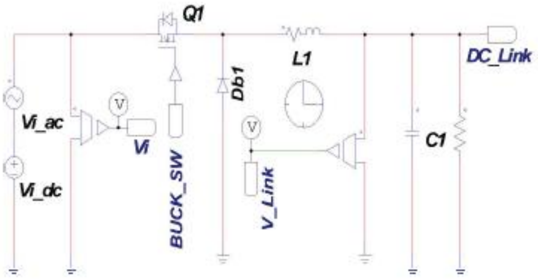
$$t_1 = \sqrt{\frac{2L_1}{V_i(V_i - V_{DC})}}\omega \quad (4)$$

Therefore, the duty ratio to generate the desired output is as follows:

$$d = \sqrt{\frac{2L_1P_0}{\eta V_i(V_i - V_{DC})}}f_{max} \quad (5)$$

## III. SIMULATION RESULT

In order to explore issues around Web specification processes and what characteristics are typically figure 5 is a circuit diagram for examining the validity of the proposed technique. Figure 5(a) shows the non-isolated step-down converter to transfer constant energy, Figure 5(b) the isolated flyback converter, Figure 5(c) loads, and Figure 5(d) the dll file interface to implement the switching algorithm proposed by this paper, respectively.

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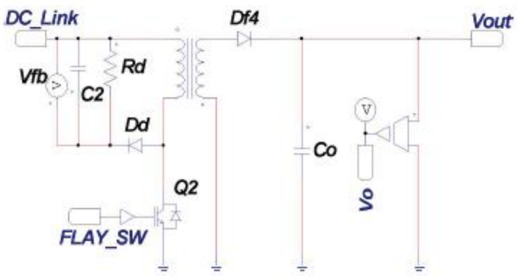


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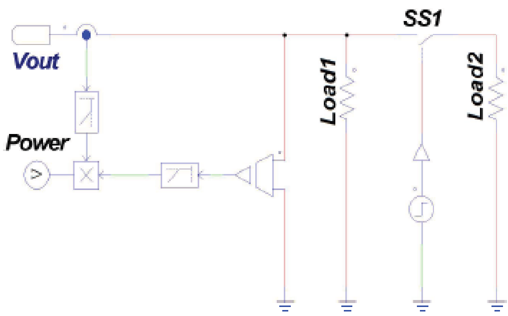


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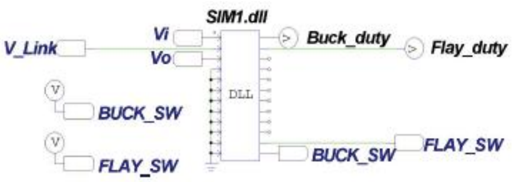
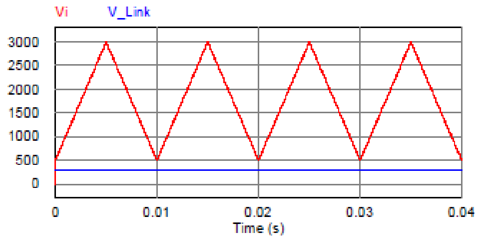



**(d)**

**Figure 5. Simulation circuit**

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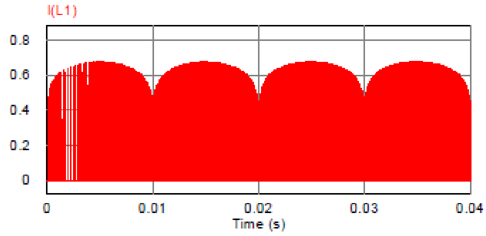


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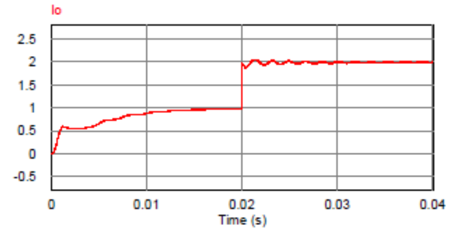


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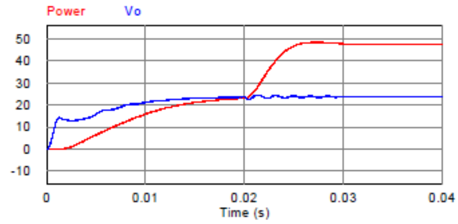


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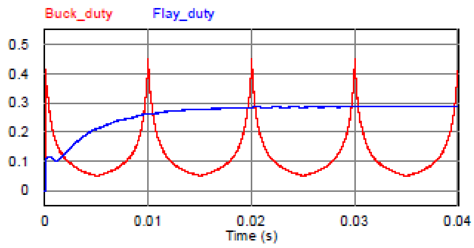


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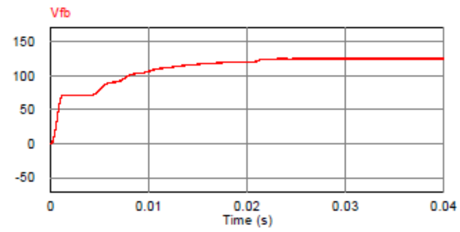


**(f)**

**Figure 6. Result of simulation**

Figure 6 shows the results of simulation, and figure 6(a) indicates that the output of the non-isolated step-down converter is constant at 300 [V] even when the input voltage changes from 500 [V] to 3000 [V]. As shown in the figure, the greatest advantage of the proposed switching system is that it is robust against variations in input voltage. Figure 6(b) shows the


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inductor current of the non-isolated step-down converter, and indicates that the peak current of the inductor changes so as to output constant energy according to varying input voltage. Figure 6(c) shows the load current waveform in case that the load of 24 [W] is applied at starting and 48 [W] is applied 20 [ms] after starting. Figure 6(d) shows the output power and the output voltage. As seen in the figure, the output voltage forms stable voltage after 10 [ms] even when the output changes from 20 [W] to 40 [W]. Figure 6(e) shows the switching duty ratios of the non-isolated step-down converter and the isolated flyback converter. To transfer constant energy, the duty ratio of the step-down converter changes from 0.05 to 0.45 depending on input voltage variations to form the stable output voltage of 300 [V]. And as for the isolated flyback converter, the duty ratio changes so that constant voltage may be outputted from constant voltage input. Figure 6(f) shows the voltage of RDC snubber in the flyback converter, which was found to be about 120 [V].

## IV. CONCLUSION

This paper suggested a structure of two-step SMPS with a wide range of variations in input voltage, which is suitable to SMPS for HVDC MMC and combines a step-down conve rter and a flyback converter, and proposed a new switching t echnique that is robust against variations in input voltage an d can output constant energy control. The control system of the proposed step-down converter is a switching system that can output constant energy in the discontinuous current cont rol mode, and the control of output voltage is made by outpu t voltage detection and discontinuous frequency control. The results of simulation showed that the output voltage of the non-isolated step-down converter is constant and operates st ably even in case of 100 [%] load variation, and the isolated flyback converter outputs constant output voltage with const ant input voltage; and from this, it is deemed that high effici ency will be achievable.

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