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Closed Loop Action Of Improved SEPIC Converter Through Improved PI Regulator

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Abstract:

Generally renewable energy resources are getting combined through DC micro grids towards distributes reliable electrical energy through enhancing structure productivity and essential price saving in the best way. Here the suggested Improved SEPIC converter is designed based on the traditional SEPIC through a boost-up module. In this research work, closed loop control of Improved SEPIC Converter for DC micro grid is also analysed and achieved simulation results of continuous output current, output voltage stability in improved manner through reducing the peak over shoot of output voltage wave form comparing through the open loop control of Improved SEPIC Converter by the application of PSIM software.

Keywords: Improved SEPIC Converter (MSC), closed loop control of MSC, Improved PI Regulator, DC micro grids, DC loads

1. INTRODUCTION

The low level of DC voltage convert into high level and vice versa is done through the switched mode DC-DC converters by switching Technique. These DC-DC converters are widely used in telecommunication equipment's, appliance control, air crafts, personal computers and etc. This DC-DC converter's control and stabilization is needed for better regulation of output voltage of DC micro grid applications [1-2]. FIGURE 1, illustrate the applications of DC-DC converters in different areas.

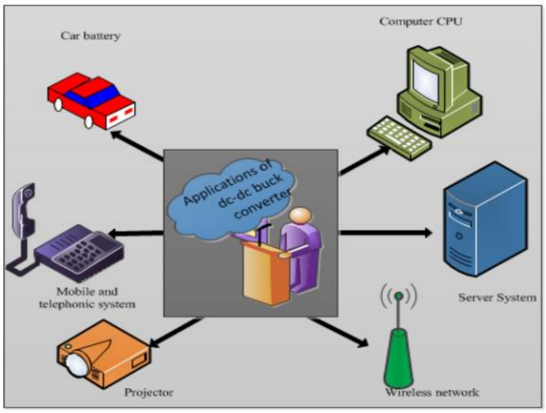

FIGURE 1. Applications of DC-DC converters

Many control methods are implemented through their merits and demerits for industrial and domestic applications [3]. In earlier days two control methods are more popular and simple in structure through low cost Regulators such as voltage and current mode controls. Still now these two methods are widely used in academic laboratories, industries and etc. Furthermore each control technique can satisfies the demand of the DC loads through their best performance.

Several different control techniques are deliberated in earlier articles [4-16], such as the current and voltage mode control methods, regular K-factor method and etc. can regulate and stabilize the DC-DC converter's output voltage from the input source of PV arrays [6] or battery voltage[9] through distorted variations are applied to these the DC-DC converter. Especially to control the output voltage of the DC-DC converter, most of the researchers are suggested that only voltage mode control is chosen for DC-DC converter through step down DC loads based DC micro grids.

Voltage mode control (VMC) is a common control technique [17] and widely used in control engineering applications due to its simplicity and better controlling in output voltage even if there is any changes in DC load. In VMC, the DC-DC converter's output voltage is measured and associated through the reference voltage. The desired output voltage of the DC-DC converter compared through actual output voltage and utilized this voltage as an input to a Regulator. Then Regulator generates resultant voltage to the PWM comparing to this resultant voltage through some ramp signal voltage to generate required duty ratio for desired constant DC output voltage. Consequently, other control methods such as current mode control and hysteresis control techniques are requisite some information regarding the output current, output voltage delay generated by the Regulator, type of the Regulator used and etc. But the Regulator in the voltage mode only needs output voltage and then produces stable voltage the DC-DC converter. VMC able to step down the supply voltage and formerly produces an output voltage through proper regulation for small DC loads and vice versa.

In most of the cases VMC can applied to the DC-DC converter can regulate and stabilize the output voltage in precise manner for DC micro grids. The response time of the output voltage varies in between 0.06 to 0.08 sec by this control technique applied to this DC-DC converter. The VMC through ImprovedPI Type II Regulator can produce an output voltage in accurate manner throughin the less response time (in between 0.02 to 0.04 sec) of VMC DC-DC converter if the DC-DC converter's input voltage can change in periodically [18].

In earlier day's traditional buck-boost, SEPIC, CUK type non-isolated DC-DC converters through VMC through maximum duty ratio technique can be utilized for high voltage applications. But these traditional DC-DC converters are operated at maximum duty ratio [approximately varies in 0.85 to 0.95] can reduces the efficiency and disturbs the Action of the converter. Finally these converters are somewhat produces transients even if they are operated in closed loop control technique. So, researcher's focuses' on SEPIC converter to design as like a ImprovedSEPIC Converter (MSC) [19] to get a high voltage gain and produces a continuous current to the DC loads.

Finally the remaining article organises as follows; section-3 gives small introduction of closed loop Action of MSC, Section-3 evaluates the PSIM simulation results of both closed loop Action of MSC and finally, Section-5 concludes the article.

2. CLOSED LOOP ACTION OF MSC

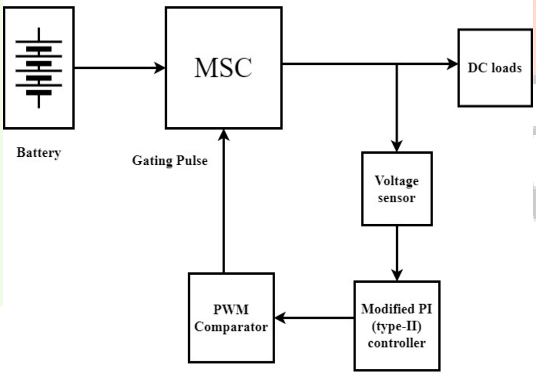

FIGURE 2. Block diagram of the closed loop control of MSC

From block diagram in FIGURE 2, contains one dc source input like as (battery, PV and etc.), DC load, MSC, Improved PI Regulator, voltage sensor and PWM comparator. In this block diagram, the output voltage of MSC is sensed by voltage sensor and compares this voltage through a DC reference voltage through ImprovedPI type-II Regulator (Type-II error amplifier). If any difference is made then Type-II error amplifier can amplifies the difference. At PWM comparator, error voltage achieved from the error signal compared through voltage of the ramp signal to generate a required duty ratio desired through the output voltage of the MSC. If error voltage is larger than the voltage of the ramp signal, then output of the PWM comparator becomes high and vice versa. Subsequently, duty ratio always depends on error voltage. If this error voltage is increased then the longer the duty ratios to trigger the power switch of MSC. Finally constant DC output voltage is appeared at DC load driven by the MSC.

In this section simulation results of both closed loop and open loop control of MSC are discussed and analysed. The closed loop control of MSC's output voltage waveform is settles in less than 0.02 sec. But the output voltage waveform of the open loop control of MSC is settles at 0.1 sec. Moreover the closed loop control of MSC's output voltage waveform is constant even if any transients are present in its input. But open loop control of MSC's output voltage waveform is not exactly constant, because transients are present in its input. Similarly above points regarding the output voltage of the closed and open loop control of MSC are applicable to the output current of the open and closed loop control of MSC.

3. SIMULATION RESULTS OF CLOSED LOOP CONTROL OF MSC

Here input voltage through disturbances is feed to the MSC. And then output voltage of MSC is producing some transients in its output voltage waveform. Here performance parameters under time domain specifications are evaluated for the closed loop control of MSC's output voltage.

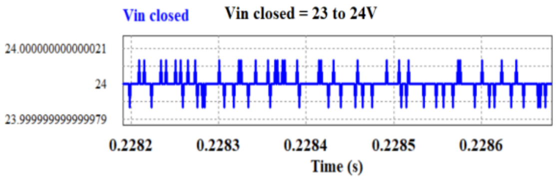

FIGURE 3. Input voltage $V_{in\ closed}$

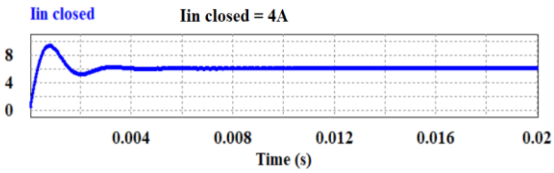

FIGURE 4. Input current $I_{in\ closed}$

FIGURE 3 and 4, are illustrates the input current and voltage wave forms of the closed loop control of MSC. Here input voltage is 24V and input current is 4A of the closed loop control of MSC. The waveforms in FIGURE 3 and 4, regarding the closed loop control of MSC are having some disturbances. Then this input current and voltage are feed to MSC and finally output voltage and current of closed loop MSC are viewed at DC loads driven by MSC.

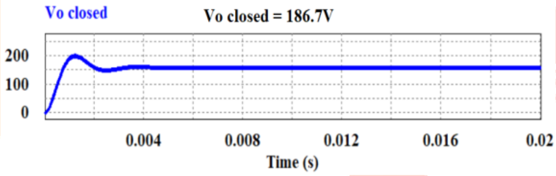

FIGURE 5. Output voltage $V_{o\ closed}$

FIGURE 5, can express the closed loop MSC's output voltage, damping ratio(θ), un-damped natural frequency (ω_n) and damped natural frequency (ω_d) parameters are considered on the basis of logarithmic decrement method [23].

Damping ratio (θ) = 0.6, Un-damped natural frequency (ω_n) = 1.8 rad/sec, $\omega_d = \omega_n\sqrt{1-\theta^2}$ = 1.4 rad/sec, and here $\beta = \cos^{-1}\theta$. The mathematical calculations described in TABLE 1, demonstrates that peak overshoot value is 9.48 % , Delay time, peak time and rise time are at less than 2 sec and finally settling time is at 3.7 sec regarding the closed loop control of MSC's output voltage. If the MSC's output voltage can controlled by Improved PI type-II Regulator then output voltage of this MSC definitely produces less transients, peak overshoot nearly at 9 % and settling time this output voltage waveform is at nearly 4 sec. So these values prove that closed loop control of MSC can't generate constant DC output voltage in the period of less than 0.02 sec. After 0.02 sec closed loop MSC generate constant DC output voltage at DC load side. That's the reason closed loop control of MSC can easily eliminates all transients and disturbances produced by external sources after 0.02 sec for output voltage of closed loop MSC.

TABLE 1. Evaluation of performance parameters of output voltage of the closed loop control of MSC

Performance parameters	Formulae	Values
Delay time (T_d)	$T_d = \frac{1 + 0.7\theta}{\omega_n}$	0.8 sec
Rise time (T_r)	$T_r = \frac{\pi - \beta}{\omega_d}$	1.53 sec
Peak time (T_p)	$T_p = \frac{\pi}{\omega_d}$	2.18 sec
Peak overshoot (%M_p)	$\%M_p = 100e^{-\frac{\pi\theta}{\sqrt{1-\theta^2}}}$	9.48 %
Settling time (T_s)	$T_s = \frac{4}{\theta\omega_n}$	3.7 sec

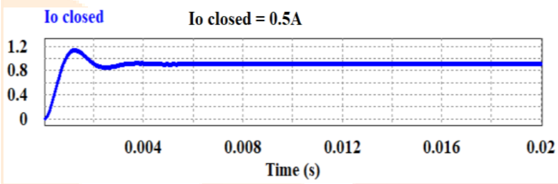

FIGURE 6. Output current $I_{o\ closed}$

The mathematical calculations described in TABLE 1, regarding the output voltage waveform of the closed loop control of MSC demonstrates in FIGURE 6, that peak overshoot value is 9.48 %, Delay time, peak time and rise time are at less than 2 sec and finally settling time is at 3.7 sec are similarly applicable for the closed loop control of MSC's output current. If the output current of MSC can controlled by Improved PI type-II Regulator then output voltage of this MSC definitely produces less transients, peak overshoot nearly at 9 % and settling time this output voltage waveform is at nearly 4 sec.

So these values prove that closed loop control of MSC can't generate constant DC output current in the period of less than 0.02 sec. After 0.02 sec closed loop MSC generate constant DC output current at DC load side. That's the reason closed loop control of MSC can easily eliminates all transients and disturbances produced by external sources after 0.02 sec for output current of closed loop MSC.

5. CONCLUSION

The conclusion of this article inferred that closed loop control of MSC performs better control action in its output voltage through a ImprovedPI type-II Regulator. The simulation results regarding the output voltage of closed loop MSC is constant in DC manner. After 0.02 sec closed loop MSC generate constant DC output voltage and current at DC load side. Then closed loop control of MSC can easily eliminate all transients and disturbances produced by external sources after 0.02 sec for output current of closed loop MSC.

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