A Nine-Switch Power Conditioner for Power & Voltage Profile Improvement

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Abstract— A nine switch power conditioner is proposed instead of back-to-back converter. It has certain advantages over back to back converter. It contains nine switches compare to twelve switches back-to back converter. Additional advantage is that it has component saving topological feature. It is used in limited application due to oversized dc link capacitor, constrained phase shift between two output terminal and limited amplitude sharing. The novelty of this method is that the middle switch is shared by the inverter and rectifier mode. The designed control scheme is incorporated here. The validity of proposed nine switch power converter is verified through simulation.

Keywords- *Nine-switch converter, carrier- based pulse-width modulation technique, power conditioner, power quality.*

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I. INTRODUCTION

Now a day's many converter technologies are readily used because of variable power converter are grown rapidly [1] and which is used in various application [2]. All these power converter is used for power quality improvement and minimization of voltage sag. Most of the power electronic converter are used to be connected in shunt and series manner [3] and [4]. They require to be voltage, current and power regulation. That is why they will help for compensating harmonic, reactive power flow unbalance and voltage regulation.

The purpose of shunt and series converter is to improve the power quality. Shunt converter is used as voltage regulation while series converter is used as current regulation. These two converter are connected in back-to-back configuration that is why they called as back-to-back converter [5]. In back-to-back converter 12 switches are used and out of these 12 switches six switches are used as shunt converter and remaining six switches are used as series converter. The common dc link capacitor is used between the shunt and series converter as micro source. Fig.1. shows the back-to-back converter. The drawback of this back-to-back converter is some amount of complexity in system and separate control is required for series and shunt converter.

Another semiconductor topology can be found in [6]. In that system reduced number of switches is consider is known as B4 converter topology. B4 converter uses four switches and its third phase is drawn from the midpoint of the spilt dc capacitive dc link [7]. For connecting two ac system together it maintaining the Integrity of the Specifications is needed two B4 converter to be connected with sharing its dc capacitor link. Thus total number of switches required is 8 so it is known as B8 converter. The B8 converter has certain disadvantages its suffer from large dc link capacitor voltage variation and the fundamental current is not flowing through the system unless both system has same frequency synchronization with grid system.

To minimize the problem of back-to-back converter classical alternative direct and indirect matrix converter method can be used in system. This system having 18 switches this system represents six switches more than back-to-back system

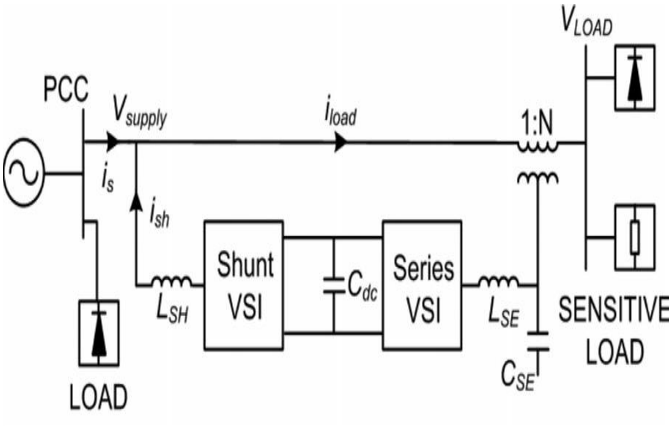

Fig. 1. Back-to-back converter

the advantage of this matrix converter method is it does not require dc link capacitor. This system is also not useful for voltage buck and boost operation. Matrix converter is divided into two part one is heavy switch count and other is minimum switch count but problem in this system is its support only unidirectional power flow [6] and [7].

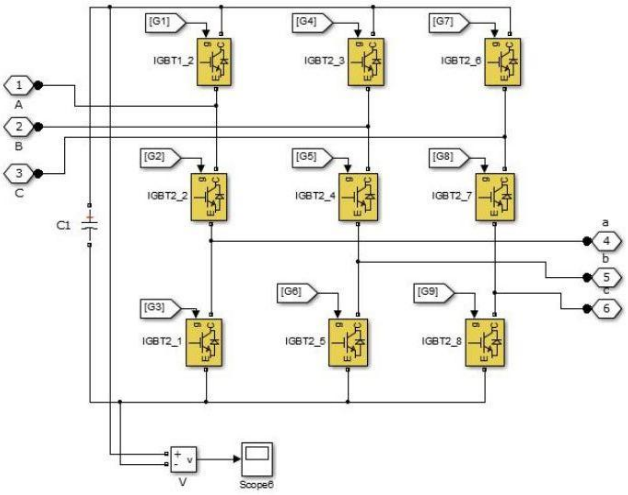

Fig. 2. Proposed Nine-switch converter

Overcoming the disadvantage of B4 converter by using five leg converter which is introduced in [10]. Conceptually one extra leg is added to the B8 converter. The two interfaced ac system will now shares the added phase leg with now no large fundamental voltage variation across the dc link. The only constrain is that it is only useful for common frequency operation on the two interfaced ac system and therefore it is unsuitable for application like series shunt power converter and utility power adjustable drives.

Overcoming all these constrain by using single stage integrated nine switch power conditioner shown in Fig.2. It having two sets of output terminal compare to the 12 switches back-to-back converter. It has some advantages minimum switching count, reduction of commutation, reduced semiconductor technology because of this cost of system is much reduced.

II. NINE SWITCH POWER CONVERTER TOPOLOGY AND SWITCHING SCHEMS

Figure 2 shows the Nine-switch power conditioner. Three semiconductor switches are used in each leg. Nine IGBT are used in this topology for AC/AC conversion through dc link capacitor. The advantage of this topology is it draws sinusoidal current, forward losses is less, unity input power factor and more important is low manufacturing cost. Anti parallel diode is connected for bidirectional power flow. DC link capacitor is used as either micro source or storage capacitor depending upon the system. Nine switch converter switching states are shown in Table I. Nine switch converter can connect its two output terminal per phase to either V_{dc} or 0 v , or its upper terminal is connected to the upper dc rail P and lower terminal to N and the limitation of nine switch converter is the combination of connecting its upper terminal to N and lower terminal to P is not realizable. This limitation is not practically detrimental. This can be solved by using coordinating two modulating reference per phase. This can be resolved by using reference for the upper terminal is above the lower terminal. Gating signal is provided to the IGBT or switch S_1, S_2, S_3 by using logical XOR operator. Logical equations for producing gating signal are shown below. Where XOR is the logical XOR operator. Fig .3. shows the arrangements of references having the same frequency but different amplitudes.

switching states of nine switch power converter is shown in a Table I. In nine switch power converter input and output voltage is independently controlled. Middle switch is shared by rectifier and inverter. V_{AN} And V_{RN} are the voltages at node A and R with respect to negative dc bus N. when switch S_1 and S_2 of converter first leg is ON then output voltage is $V_{AN} = V_{RN} = V_{dc}$ when switch S_1 is off and remaining two switches are ON then output voltage is $V_{AN} = V_{RN} = 0$. When middle switch is turned OFF and other two switches are ON then output voltage is $V_{AN} = V_{dc}$ and $V_{RN} = 0$.

The forbidden state of $V_{AN} = 0V$ *and* $V_{RN} = V_{dc}$ *is blocked. This blocking is attained at the exposure of additional constrain Equations which limit the reference amplitude and phase shift. This limitation is important for the reference having sizable amplitude and different frequency.*

Middle switch in each leg is shared by the inverter and rectifier therefore reducing the switch count by 33% compare to back-to-back converter. It should be pointed that modulation index of rectifier is always greater than inverter modulation index its does not mean that inverter output voltage is always less than rectifier output voltage. In fact inverter output voltage is greater than rectifier because of rectifier boost operation.

$S_1 =! S'_1$ {ON, if upper reference is larger than carrier
OFF, Otherwise

$S_3 =! S'_3$ {ON, if lower reference is smaller than carrier
OFF, Otherwise

$$S_2 = S'_1 \text{ XOR } S'_3 \quad (1)$$

TABLE I. SWITCH STATES AND OUTPUT VOLTAGE PER PHASE

S_1	S_2	S_3	V_{AN}	V_{RN}
ON	ON	OFF	V_{dc}	V_{dc}
ON	OFF	ON	V_{dc}	0
OFF	ON	ON	0	0

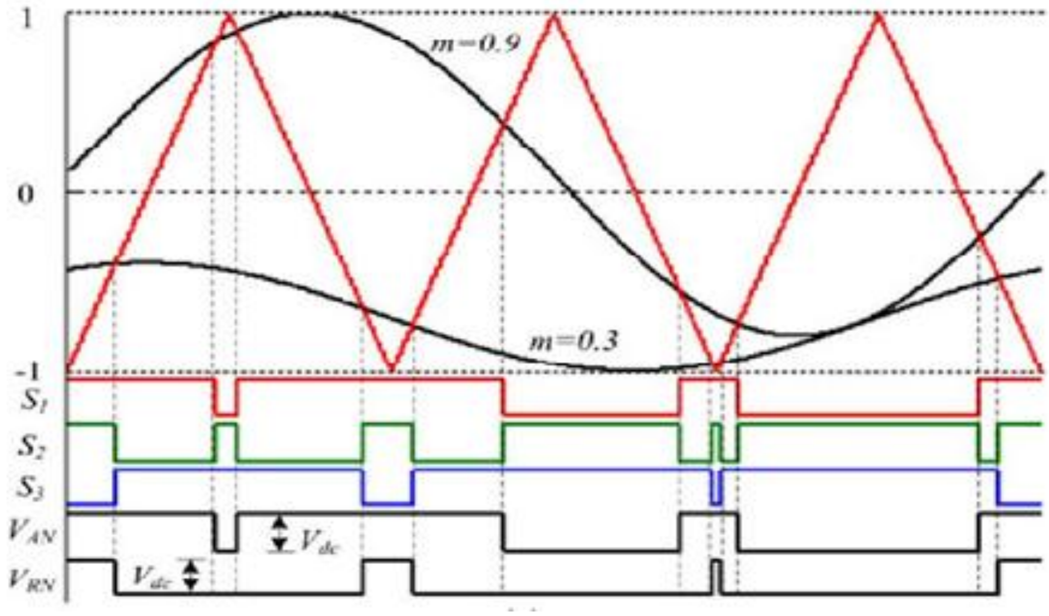

Fig.. 3. Arrangements of references having the same frequency but different amplitudes

Modulation wave of the rectifier and inverter is for the DC component and inverter output voltage adjustment. Modulation indices of inverter and rectifier can be independently adjustable from zero to unity. It can be clearly seen modulation scheme satisfy the switching operation of nine switch converter. modulation wave of inerter and rectifier contains the DC component.

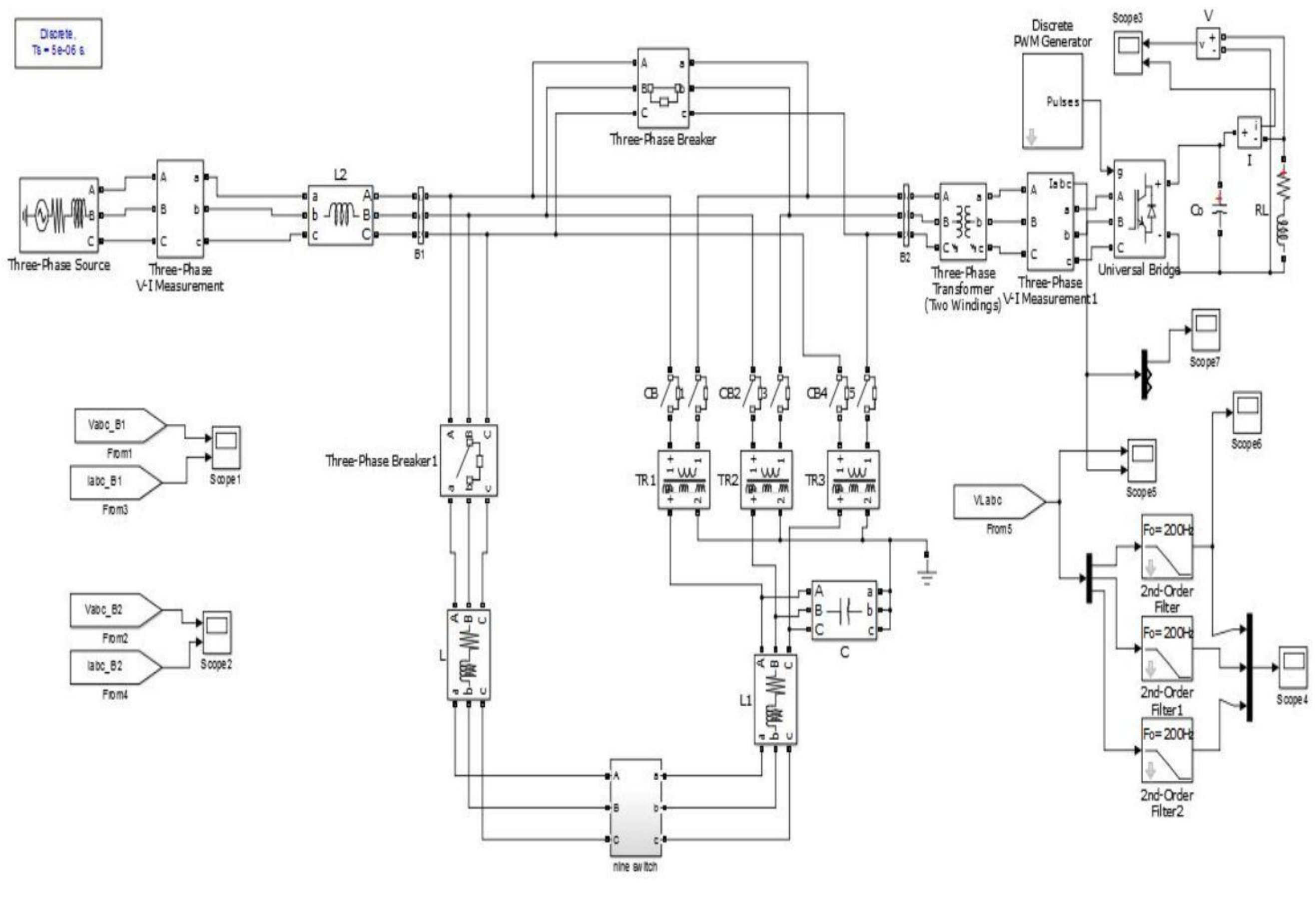

Fig. 4. Simulated Proposed System

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III.PROPOSED NINE-SWITCH POWER CONDITIONER

In normal operating condition output voltage amplitude of the shunt converter is more than the voltage drop of the series converter so modulating reference of shunt converter is much larger than the series converter drawing these details in wider carrier range then modulating signal of shunt converter has wider vertical range h_1. Fig.3. shows that h_1 is used for controlling shunt terminal and h_2 for the controlling series terminal when if an ideal connection then h_2 can be set to zero because of no distortions and rated sinusoidal voltage. For ideal grid connection in that case switch S_3 should be kept ON and because of this series transformer will be shorted for avoiding unnecessary switching losses. If desired we can also bypassed series transformer without affecting shunt converter compensation ability.

In fig.3 h_1 and h_2 carrier band shown. Fig.3 would still require increase in dc link voltage but in UPQC voltage of dc link is not increased. The modulation ratio of series converter is low 0.05*1.15 with third harmonic included. Increase dc link voltage up to 5% by the nine switch converter and obtain same shunt voltage magnitude with reducing the maximum modulation ratio of 0.095*1.15 instead of 1.15 with third harmonic is considered.

The nine switch power converter is indeed method for normal operating condition and voltage sag condition. For this method need to be some voltage drop should be occurred after the shunt converter. The series converter will inject the sizable series voltage at fundamental frequency. Therefore nine switch converter method is suitable for 'Series-Shunt' converter. Where Vseries = Vload – Vsupply Where Vload is the load voltage so that load keep close to the pre fault level.

In fig.4. simulation shows nine switch converter is connected to the system. System has non linear load because of this non linear load voltage sag is produced in the system. In this simulation model non linear load which is connected to the source through the circuit breaker up to some specified operating time 0.5 after 0.5 second circuit breaker is open between the source and the non linear load and after 0.5 second nine switch converter is connected to the non linear load through circuit breaker which is closed at 0.5 second. After connecting nine switch converter to the system it inject current and voltage in system because of this injecting voltage to the system voltage profile and power quality is increased and system behave normal.

IV. SIMULATION RESULTS

The proposed single stage integrated nine-switch power conditioner model shown in Fig.2. It is simulated by using MATLAB/SIMULINK. Simulation parameters are listed in Table II. And also performance of proposed nine-switch conditioner is evaluated with the help of MATLAB simulation model.

TABLE II. SIMULATION PARAMETERS

Parameter	**Value**
Supply voltage	400V
C_{dc}	1500µF
$R+L_{shunt}$	1ohm+5mH
$R+L_{series}$	2ohm+0.5mH
C_{series}	30µF
C_{load}	4000µF
$(R+L)_{load}$	150ohm+150µH

Figure 5 shows the THD is reduced from 48.59% to 0.88%

during SAG to NORMAL operation that is after compensation of nine-switch power conditioner.

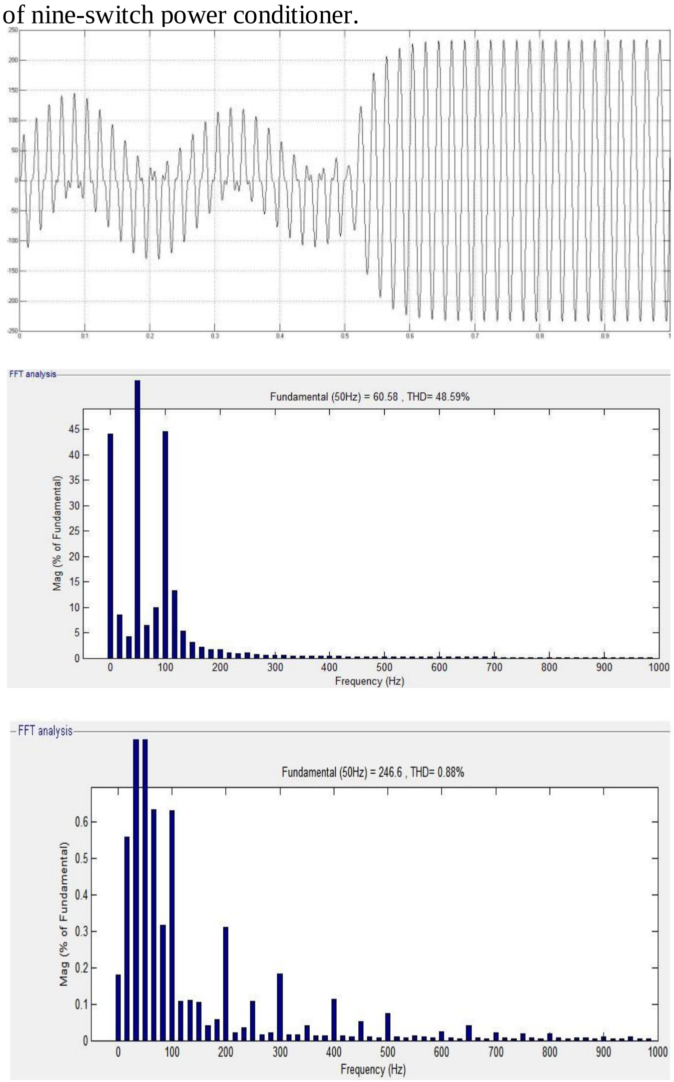
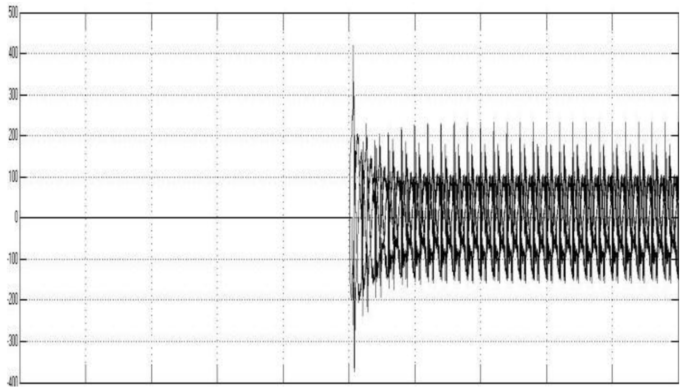


Fig. 5. Supply voltage, FFT analysis during Sag, FFT analysis during Normal condition

Figure 6 shows series injection voltage and shunt injection current by nine-switch power conditioner during the sag to normal condition.



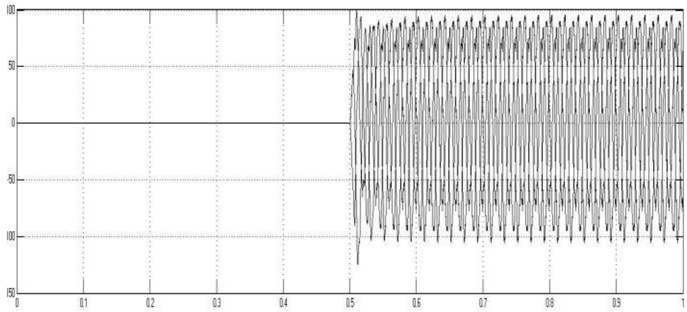


Fig. 6. Series injection voltage and Shunt injection current during sag to normal condition

V. CONCLUSION

The single stage nine-switch power conditioner is good equipement for voltage sag mitigation and harmonic distoration. It has less switches compered to the conventional back-to back converter therefore it is suitable for the replacement of the back-to-back converter. It is simulated in MATLAB/SIMULIK. The carrier based modulation siganal is used for the reducing commution. Therfore nine switch converter has proved it is effective and it has a smooth peformance.

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