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# ADVANCED FLEXIBLE MULTIPORT POWER ELECTRONIC TRANSFORMER FOR HIGH VOLTAGE APPLICATIONS

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## ABSTRACT

**Aim**: To develop a multiport electrical system that converts variable input wave form to the desired output waveform, In addition for high voltage applications (or) three phase systems. **Methodology**: It is constructed with modules on a common dc link reduced switch topology. A novel voltage source full bridge dc-ac converter with phase shift modulation using high frequency cycloconverter is proposed. Both zero voltage and zero current switching (ZVZCS) commutation for full bridge active power switches and zero voltage switching for cycloconverter bi-directional switches are obtained. **Results:** The simulation results show that in FMPET the port can be connected in series to obtain high voltage and connected in star for three phase applications maintaining the port voltage constant during voltage swell and sag. **Conclusion:** Based on the requirement of a flexible power conversion system MPET is proposed to facilitate many requirements that are expected in power electronic and distribution systems. The proposed topology is flexible enough to provide bi-directional power flow and has as many ports as it is required.

***Key words**: DC Link, Power Electronic Transformer, Phase Shift Modulation and ZVZCS.*

## INTRODUCTION

One key component of the future automation in electrical networks is the replacement of conventional transformers by an Power electronic transformers (PETs) and perform voltage regulation and power exchange between generation and consumption by electrical conversion(Hosseini *et al.,* (2008) and Hosseini *et al.,* (2008a)) The previous researches show that PETs have a great capacity to receive much more attention due to their merits such as high-frequency link transformation and flexible regulation of the voltage and power. Although many studies have been conducted on application and control of PET in power systems (Hosseini *et al.,* (2008), Hosseini *et al.,* (2008a) and Huasheng *et al.,* (2005)) less attention is paid to the areas of the circuit topologies (Huasheng *et al.,* 2005). The topology of PET can be developed in such a way to achieve multiport electrical system that converts variable input waveform to the desired output waveform. In addition, for higher voltage applications or three phase systems, the topology is expandable as it is modular.

In this paper, a new PET topology named flexible power electronic transformer (FMPET) is proposed. As shown in Fig. 1, it is constructed based on modules and a common dc link, which is used to transfer energy between ports and isolate all ports from each other. In this bidirectional topology, each port can be considered as an input or output. Each module consists of three main parts, including modulator, demodulator, and high frequency isolation transformer (HFIT). The modulator is a dc–ac converter and the demodulator is an ac–ac converter; both with bidirectional power flow capability. Each module Fig.1: Main concept of proposed FMPET operates independently and can transfer power between ports. These ports can have many different characteristics, such as voltage level, frequency, phase angle, and waveform. As a result, FMPET can satisfy almost any kind of application, which are desired in power electronic conversion systems and meet future needs of electricity networks. Considering this point, it is named flexible. The simulation results of high-voltage application are given to clarify the advantages of the proposed FPET over the recently developed PETs (Aijuan *et al.,* 2006).

## PROPOSED POWER CIRCUIT OF FMPET

The proposed circuit is shown in Fig. 2. It should be mentioned that the proposed topology can be expanded by connecting modules in series or parallel to obtain higher voltage or current ratings, and to form star/delta connections for three phase applications. Fig 2 shows the reduced switch topology, In this case, one of the half-bridge circuits can be considered as the reference or master leg. Once gate pulses for the master leg (i.e., switches and) are provided, the gate pulses of the other legs (slave legs) have a phase shift respect to the master leg. The modulator (full bridge dc link inverter) can be described as follows:

1) Bidirectional power flow capability;
2) Adjustable switching frequency that feed voltage pulses frequency into the pass band of HFIT; and
3) Stored energy in the dc link (if the modulator is in active rectifier mode).

The demodulator (cycloconverter) converts high frequency voltage (i.e.,) to low frequency voltage (i.e., $Vpr1$) and *vice versa*. The specifications of the demodulator are listed as follows:

1) Bidirectional power flow capability; and
2) Providing zero voltage switching by turning the switches of cycloconverter ON/OFF, while voltage of HFIT riches to zero.

**MODULATION AND DEMODULATION OPERATION PRINCIPLES**

The well-known phase shift modulation (PSM) method is shown in Fig. 3. The definition of parameters is given in Table I. The voltage regulation is performed by the FBDCI using PSM method. The cycloconverter chooses the PSM pulses in such a way to provide positive or negative voltage polarity at the output. In this figure, the cycloconverter provides positive output voltage polarity as an example. On one hand, the switches of cycloconverter turn ON/OFF with a time delay ($Tcd$ ) respect to those of FBDCI, so they operate under zero voltage condition. On the other hand, the switches have a small overlapping time to provide a path for $Lf$ current to avoid high stresses at switching instants. Thus, the switches operate at soft switching condition. The leakage inductance of HFIT should be minimized as much as possible. In practice, snubber circuits must be used to damp the stored energy in the leakage inductance of HFIT.

According to Fig. 3, the duty cycle of FBDCI is defined as follows:

$$D(kTs) = \frac{2\mathrm{Ton(kTs)}}{\mathrm{Ts}} \quad (1)$$

The modulated voltage at the secondary side for one duty cycle is expressed by (2)

$$V_s = N V_p . \quad (2)$$

The modulated voltage at the output of cycloconverter ($V_c$ ) is determined as follows:

$V_c(t) = \mathrm{sign}(t)\,|N V_p(t)| = \mathrm{sign}(t) N V_d(t)$,

$\mathrm{sign}(t) = 1$ or $-1$, $(k-1)T_s < t < kT_s$, $k = 1, 2, ..$ (3)

Where sign($t_k$ ) function determines the polarity of $V_c$ that can be positive or negative according to the desired output voltage and presented by (4), as below

$$Sign(t) = \begin{cases} 1 \rightarrow Ga(t) = G1(t-Tcd) and\ Gb(t) = G2(t-Tcd) \\ -1 \rightarrow Gb(t) = G1(t-Tcd) and\ Ga(t) = G2(t-Tcd) \end{cases}$$

$$(k-1) < t < Ts, k = 1,2,3 \ldots\ldots \quad (4)$$

**PSM Control Circuit**

The control circuit is responsible for providing pulse gate of dc link switches and the cycloconverter. The implementation of PSM is shown in Fig. 4. The input data address consists of four lines. The first line is polarity of output voltage $sign_i$. The second line is switch-enabled of cycloconverter (Enable $C_i$). The third line is switch-enabled of dc link (Enable $S_i$). The fourth line provides the duty cycle data of the $i$th port. The enabled lines are provided by the startup and protection circuits.

**B. Utilization of Ports as a Voltage Source**

As an example when a port (assuming $i^{th}$ port) is designed to operate as a voltage source, it can provide a constant volt-age regardless of the active or reactive power that is exchange between the port and the grid. So, a controllable voltage at the output of cycloconverter can be obtained and it is given by

$$v_{ci}(t) = v_{refi}(t) \quad (5)$$

Where $v_{refi}(t)$ is the reference voltage, According to (4), one may obtain the following approximation:

$v_{ref} \approx K_c sign_i^*((k+1)T_s) N_i N_d(kT_s) D_i^*((k+1)T_s)$,

$kT_s < 1 < (k+1)T_s$ (6)

Where the asterisk symbols show the next stage values, There-fore, the duty cycle and the sign function are achieved as follows:

$D_i^*((k+1)T_s) \approx \frac{|Vref((k+1)Ts|}{KcNiVd(kTs)}$ 0<D<1,

$Sign_i^*((k+1)T_s) = sign[v_{refi}((k+1)T_s]$ (7)

Because of high switching frequency, it is expected to assume $v_{ref\ i}$ is constant over time period of $kT_s < t < (k+1)T_s$ . The duty cycle is a function of dc-link voltage ($V_d$ ($kTs$)) and the turn winding of the HFIT at the $i^{th}$ port. The block diagram of controller is shown in Fig. 5.

**High voltage application**

Fig. 6 shows the proposed HV FMPET, which should be compared with the PET, suggested in (Farhangi *et al.,* 2007). As can be seen in this figure, the ports one to five, i.e., $P1$ , $P2$ ,. . ., $P4$ are connected in series to increase the rating of the input voltage. The $RC$ circuits ($Rs$ and $Cs$ ) are connected to each port to divide high input voltage equally among the ports. The sixth, seventh, and eight ports are connected to a low voltage three-phase load. Table III lists the parameters of both FMPET and cascaded H-bridge multilevel PET. Fig. 7 shows the voltage and the current of one of the five ports of HV FMPET. Considering the phase of the sinusoidal current waveform, the port draws power from the utility grid ($v1$, see Fig. 7) with almost unity power factor. Fig. 8 shows the three phase balanced load voltages and currents.

In order to study the capability of FMPET to reduce the input voltage disturbances such as voltage swell and sag, 50% voltage swell and 50% voltage sag is applied to the supply of FMPET. Fig. 9 shows the input, load, and dc-link voltages. This is clear that the output voltage, i.e., port 6 remains almost constant during voltage sags and swells, respectively. These simulations show that the multilevel PET proposed in (Krishnaswami and Ramanarayanan, 2005) and FMPET have the same capability of the power factor correction and power quality enhancement. The advantage of multilevel PET over FMPET is its lower harmonic components in the input current. Fig. 14. Voltage and current waveforms of switches (a) $Sa$, (b) $S1$, and (c) $S3$. On the other hand, FPET has the capability of the bidirectional power flow, while the multilevel PET is unidirectional. It must be mentioned that, FMPET has one dc link and one dc capacitor but multilevel PET has two dc links in each module. In addition, the output ports of FMPET can be connected in star configuration to provide a three phase four-wire system with independent phase voltage control.

**CONCLUSION**

Based on the requirement of a flexible power conversion system, FMPET is proposed to facilitate many requirements that are expected in power electronic and distribution systems. The proposed topology is flexible enough to provide bidirectional power flow and has as many ports as it is required. The dc link plays a significant role to provide energy balance, power management in the circuit and independent operation of ports. The advantages of the FMPET are: bidirectional power flow capability of ports, module-based topology, which can be used in different forms, independent operation of ports, flexibility in power amount and direction in all ports, and double galvanic isolation between each port, as well as using only one storage element.

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**REFERENCES**

Aijuan, J., Hangtian, L. and L. Shaolong, 2006. "A new high-frequency AC link three-phase four-wire power electronic transformer," in *Proc. IEEE Conf. Ind. Electron. Appl.*, May, Pp. 1–6.

Farhangi, S., Iman-Eini, H., Schanen, J. L and J. Aime, 2007. "Design of power electronic transformer based on cascaded H-bridge multilevel converter," in *Proc. IEEE Int. Symp. Ind. Electron.*, Jun, 877–882.

Hosseini, S. H., Sabahi, M and A. Y. Goharrizi, 2008. "Multi-function zero voltage and zero-current switching phase shift modulation converter using a cycloconverter with bidirectional switches," *IET Power Electron. JNL*, 1 (2): 275–286.

Hosseini, S. H., Sharifian, M. B., Sabahi, M., Yazdanpanah, A and G. H. Gharehpetian, 2008. "Bidirectional power electronic transformer for induction heating systems," in *Proc. Can. Conf. Electr. Comput. Eng.*, May 4–7: 347–350.

Huasheng, M., Bo, Z., Jianchao,Z and L. Xuechao, 2005. "Dynamic characteristics analysis and instantaneous value control design for buck-type power electronic transformer (PET)," in *Proc. IEEE Annu. Conf. Ind. Electron. Soc. IECON*, Pp. 1043–1047.

Krishnaswami, H and V. Ramanarayanan, 2005. "Control of high-frequency AC link electronic transformer," *IEE Proc. Elect. Power Appl.* 152 (3): 509–516.

**Fig 1:** flexible power electronic transformer (FMPET)

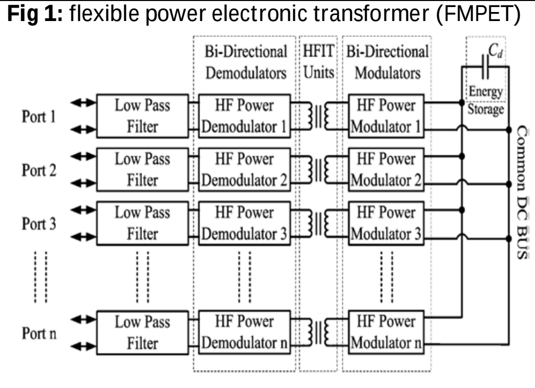


**Fig2:** Proposed FMPET circuit

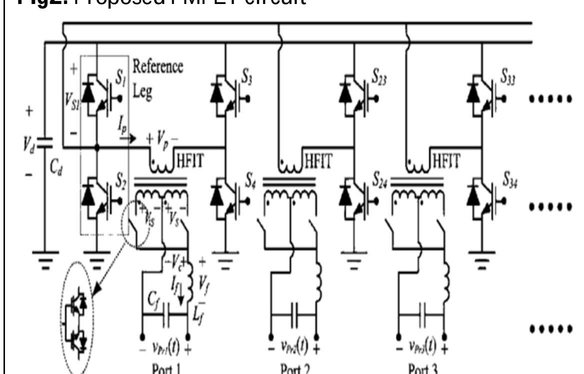


**Fig. 3:** Principle of PSM method

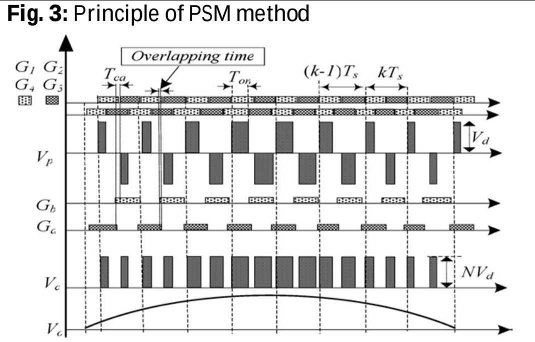


**Fig. 4.** Schematic presentation of PSM controller

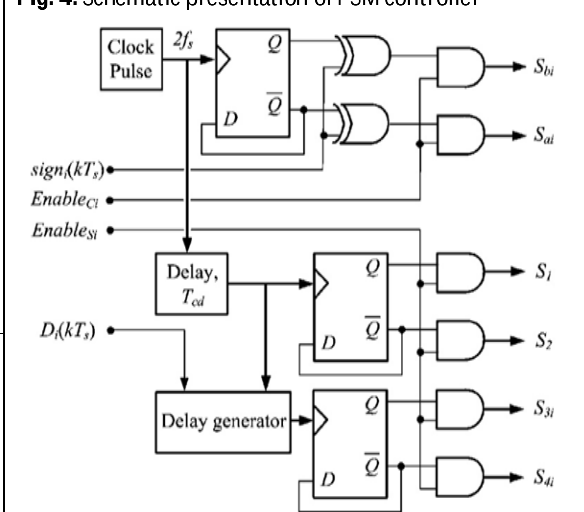


**Fig. 5:** block diagram of controller

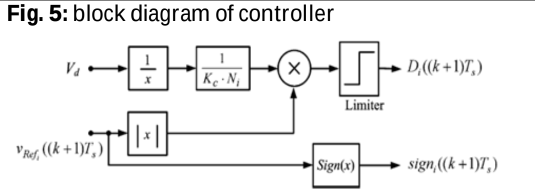

**Fig. 6:** Proposed HV MPET

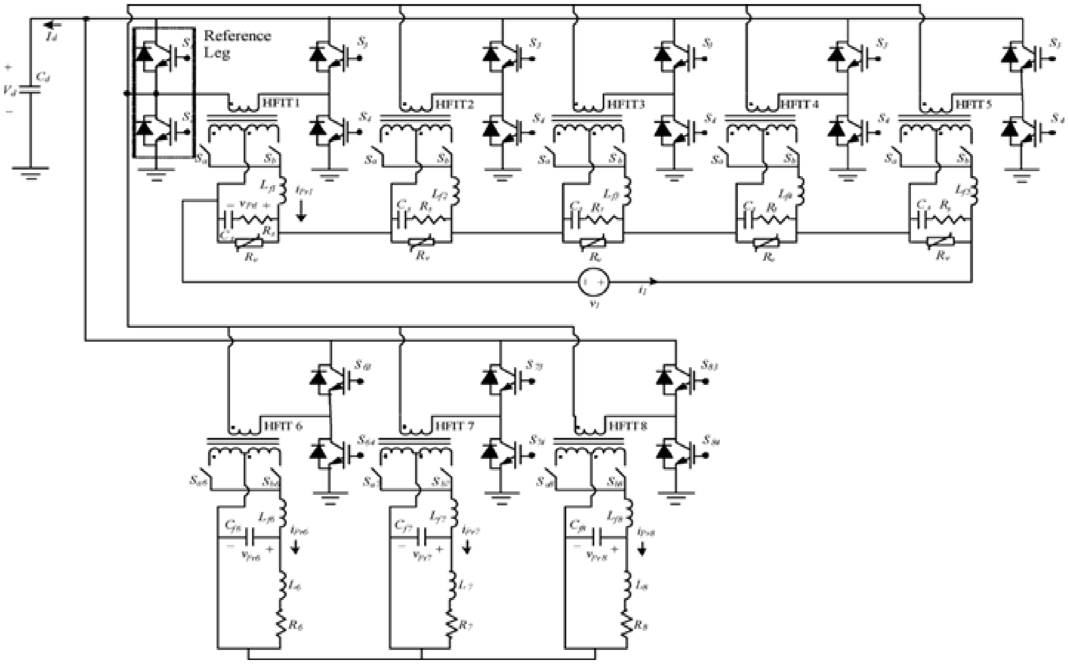


**Fig. 7.** Port voltage and current of HV FMPET.

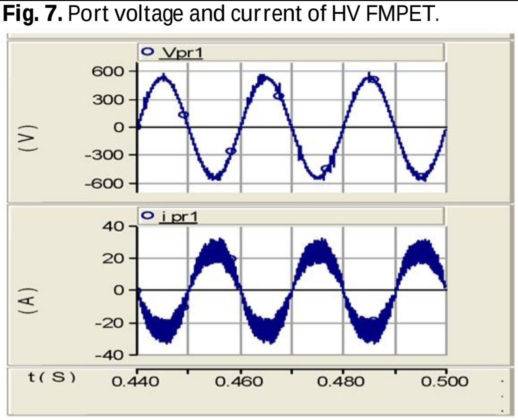


**Fig.8:** Load voltage and current of three-phase output.

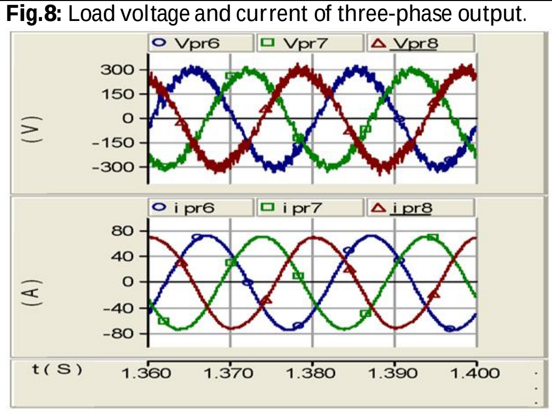


**Fig9:** Input, load and DC-link voltages

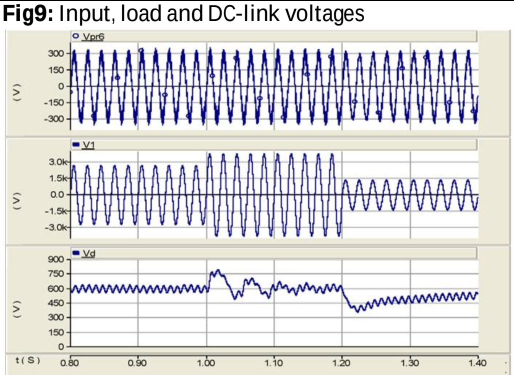


**Table 1:** definition of parameters

| Symbol | Definition |
|---|---|
| $G_i$ | Gate drive signal for $S_i$, i=1,2,3 and 4 |
| $G_a$ &$G_b$ | Gate drive signal of $S_a$ and $S_b$ |
| $T_s$ | Switching period |
| $T_{on}$ | Turn ON duration time is $T_s/2$ |
| $T_{cd}$ | Cyclo converter switch time delay |
| $V_p$ | Primary side voltage of HFIT |
| $V_s$ | Secondary side voltage of HFIT |
| $V_c$ | Output voltage of Cyclo converter |
| N | Transformer windings ratio $N_s/N_p$ |

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