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LITERATURE REVIEW ON METHODS OF LVRT IMPROVEMENT

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Abstract— International grid requirements demand low-voltage ride-through (LVRT) capability and maintaining grid functionality during fault conditions and smooth post fault recovery. As per the PV integrated grid code requirement, the PV systems must be able to stay in connected to the micro grid for power quality enhancement under grid faults and to enhance voltage profile. The unregulated output power of PV power station under abnormal conditions can be regulated through grid-friendly converters, and the power system reliability can be guaranteed depending on the performance of these power converters. Over the years, numerous LVRT control techniques have been proposed and introduced related to renewable energy technologies, which is obvious from increasing growth of relevant papers that have been published in assorted journals and proceedings. This paper presents the overview of widely adopted LVRT techniques.

Keywords—; PV Power Generation System (PVPGS), Power Quality (PQ), Voltage sag, Fault-Ride Through (FRT), Total Harmonic Distortion (THD).

I. INTRODUCTION

Based on conventional control methods, PV systems should be disconnected from micro-grids during grid faults conditions, due to the converter stability and protection. However, in recent years, a well-known requirement has set for PV systems called low-voltage ride-through (LVRT) capability, which is been applicable for other distributed generations regarding regenerative loads, compensation systems and energy storage applications [1]. In other words, the PV systems must be able to stay in connected to the microgrid for power quality enhancement under grid faults and to enhance voltage profile. The unregulated output power of PV power station under abnormal conditions can be regulated through grid-friendly converters, and the power system reliability can be guaranteed depending on the performance of these power converters. Over the years, numerous LVRT control techniques have been proposed and introduced related to renewable energy technologies, which is obvious from increasing growth of relevant papers that have been published in assorted journals and proceedings [2-5].

When fault occurs grid side, if quick disconnection of PV plants (PVPs) is carried out it may influence the grid-stability, particularly with large capacity PVPs. Hence, FRT requirements of the modern grid codes insists PVPs to remain connected when the grid voltages undergoes sags for a specific period [6]. This is required to make sure there is no loss of power generated due to commonly voltage sags. A generalized LVRT curve is presented in fig. 1, where the condition of FRT is defined as; if at PCC voltage decreases to zero for the duration of 015s the PVP must stay connected to maintain grid voltage. The PVP can be disconnected when the voltage drops to area B. Fig. 2 shows the reactive current requirement for the grid code in order to maintain the voltage profile for the condition of FRT. To fulfil the reactive power demand at the time of fault to maintain the FRT profile additional control strategies are needed to be incorporate in the control architecture of the grid connected PVP. This architecture may be within the inverter control system or external circuit need to be connected [7, 8].

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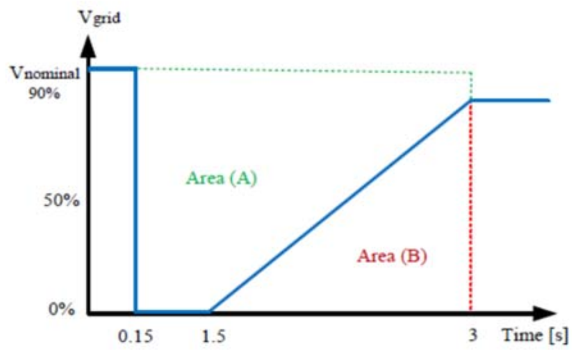

Fig 1 FRT requirement for the grid code

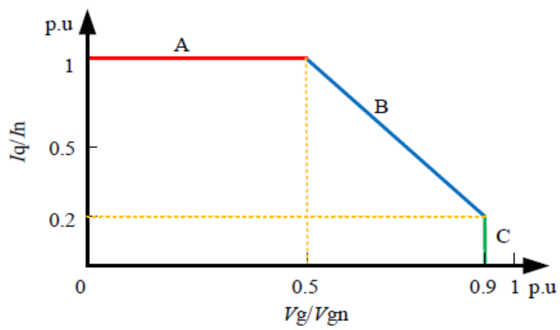

Fig 2 Reactive current requirement of FRT

II. METHODS FOR LVRT IMPROVEMENT

FRT is used to prohibit the inverter from getting tripped under short duration voltage events [9]. In FRT voltage trip time and magnitude variations is extended to a large extend in order to provide grid support. The different methods for FRT improvement under such conditions is presented in fig 3[10, 11].

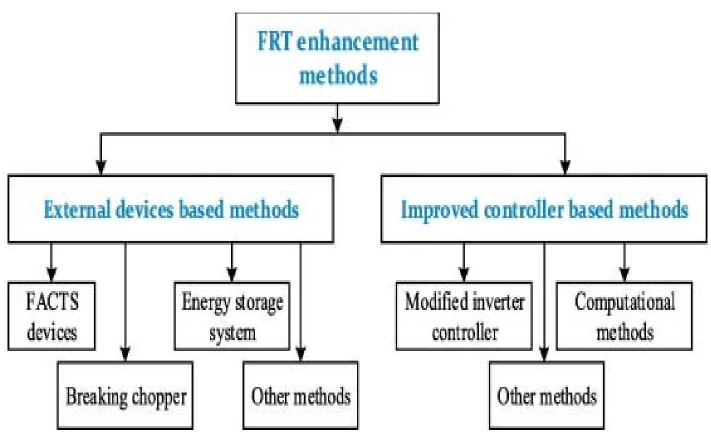

Fig. 3Methods to improve FRT

Tremendous literature available siting these methods for application in PV connected FRT capability system.

Table 1The technical comparisons among all the above mentioned methods.

METHODS	ADVANTAGES	LIMITATIONS
Storage of energy system [12-14] (fig 3.4)	Excessive energy can be stored and can reduce the AC current	It reduces the system life and leads to the Dc parameters fluctuations
Brake chopper protection [15,16] (fig 3.5)	Efficient in protecting the inverter against overvoltage	Efficiency of the system reduces
STATCOM [17] (fig 3.6)	Fast response and efficient reactive current control	Effective active power measurement is reduced and required coupling transformers also switching action is increased
Static voltage compensator (SVC) [18, 19] (fig 3.7)	Affective reactive power management and stability improvement of weak grid	Fast response causes unstable voltage oscillations
Static breaking resistor (SDBR) [20] (fig 3.8)	- High ability to restrict the excessive AC- current - Enhance the grid transient stability	Should mixed with other techniques to enhance the overall FRT performance

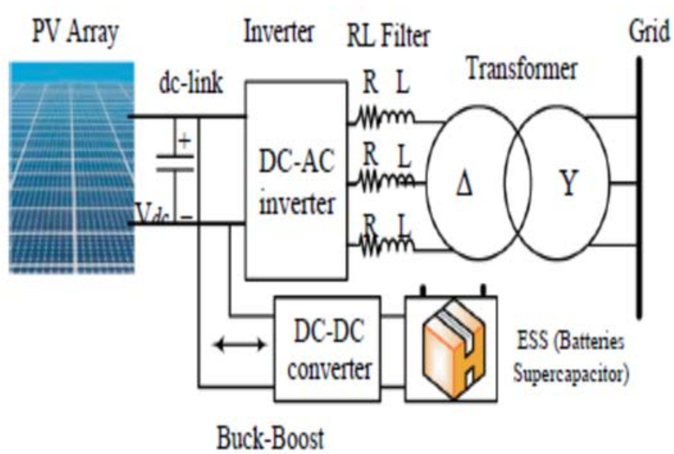

Fig-4 Fault ride-through improvement of grid-connected PV systems using energy storages.

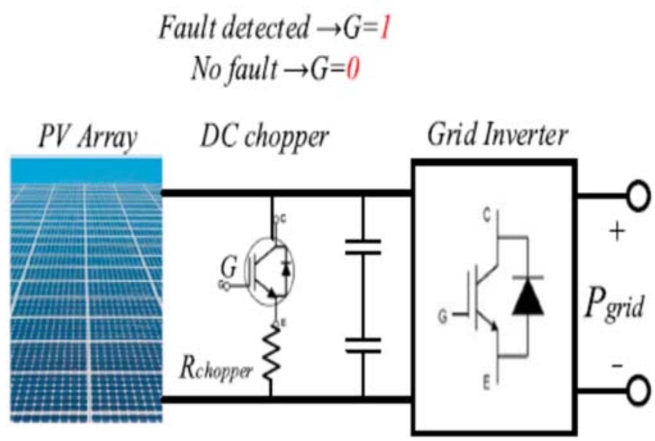

Fig-5 Brake chopper protection in the case of the FRT operation

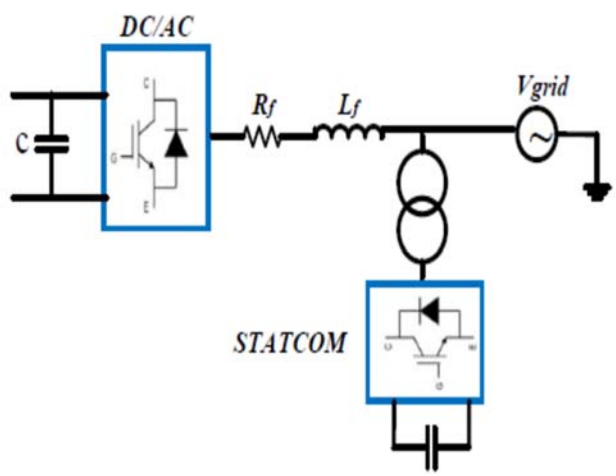

Fig. 6 Typical configuration of the STATCOM to improve the FRT performance for grid-connected PV system.

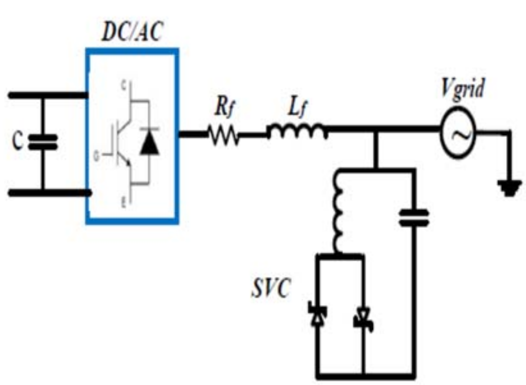

Fig 7 Typical structure of the SVC to enhance the FRT performance for grid connected PV systems.

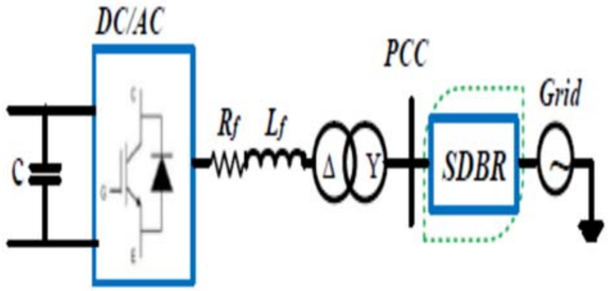

Fig. 8 Dynamic breaking resistor protection for the FRT operation.

In order to fulfil the FRT characteristics to accommodate the penetration of significant PVPs into power utility while the occurrence of the voltage sag, the control system must be capable of the following measures [21-25]: (a) fast and accurate fault identification to inform the system to switch from steady-state operation mode to the faulty one; (b) safe guard the PV inverter and other sensitive devices from the over-current that occurs at AC side; (c) safe guard the capacitor of the DC-link and the inverter from the DC-link over-voltage at DC side of the converter; (d) injection of the required quantity of reactive currents to assist the grid voltage recovery; and (e) guarantee that the PVP stays coupled to the grid for a stable operation. These measures may be classified based on their strategies for improving the FRT capability of the grid tied PVP such as, by applying:

• Sag detection unit.

• Protection circuits/devices only during grid faults.

• Reactive current injecting controllers/devices during grid faults.

• Suitable control structures during both grid faults and steady state operation.

The cost comparison and control comparison various FRT methods are presented in table 2 and 3.

Techniques	Cost	Complexity
BS (battery Storage)	High	Medium
SCS (static capacity storage)	High	Medium
BCC (Brake chopper circuit)	Medium	Medium
STATCOM	High	High
DVR (dynamic voltage restorer)	High	High
FCL fault current limiter	Low	Medium
SDBR (series dynamic breaking resistor)	Medium	Medium
MIC (modified inverter controller)	Low	Low
PSO (particle swam optimization)	Low	Medium
FLC (fuzzy logy control)	Low	Medium
DCL (direct current limiter)	Low	Low
FLS (feedback linearization strategy)	Low	Low
ADL (adaptive DC-link)	Medium	Low

III. CONCLUSION

In this paper, review techniques for the improvement of FRT capability in case ofhigh penetrated PV power generation system with grid integration under various grid conditions for voltage fluctuation is presented. A low voltage ride–through scheme enables the PV plant to remain connected under the grid fault hence improves the system stability. The LVRT/FRT enhancement can be carried out using numerous techniqueswhich are available in literature.The performance,advantages, and limitations of various strategies are also discussedin this study. Finally, a comparison of these FRT strategies interms of economic feasibility, controller complexity, additional deviceand fulfillment of FRT requirements was summarized. It can be concludedthat the overall cost and complexity of FACTS-based methodsare the highest among the others.

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