TECHNOLOGICAL ADVANCEMENTS IN GRID INTEGRATION OF SOLAR ENERGY: A REVIEW

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Abstract

Green-house gases are mainly responsible for global warming leading to the climate change. The challenges imposed by climate change have compelled to switch power generation from conventional to sustainable energy sources (SES) like solar, wind, biomass, hydro, geothermal etc. Solar is the most rapidly flourishing form of SES which is eco-friendly and has become economically viable. The power sector reforms and transition of present day grid into smart grid are facilitating bulk penetration of solar power into the conventional utility system. The authors in this paper attempt to present a paradigm shift in the development of technologies to integrate Solar Energy Conversion System (SECS) into the main grid. The SECS integration with the grid have positive as well as negative impacts on the utility system. Availability of power at the time of peak demand and even at remote locations, reduced carbon traces, reduced losses are some positive outcomes. The negative impacts of high penetration of SECS includes voltage and power fluctuations, voltage rise and reverse power flow, power factor deviations, frequency change and increase in harmonics, un-intentional islanding, fault and neutral grounding issues. Firstly, these challenges have been reviewed briefly and then technically viable solutions reported in literature have been presented. The grid management initiatives are necessary to overcome the challenges imposed by the large-scale integration of SECS. The other technological evolution of solar system such as static compensator for power quality, stability and reliability improvement are also comprehended.

Keywords: **Solar Energy Conversion System, Greening the Grid, Renewable Energy Sources, Energy Management System, Power Quality**

Introduction

For Indian economy electricity is a pillar which can be laid on the plinth of power sector reforms. The looming economic growth can be unleashed by fuelling the power sector with higher renewable energy based electricity production. The estimate of commercially exploitable potential of Renewable Energy Sources (RES) in India is about 900 GW from with major share of solar power of about 750 GW. As per the program "Greening the Grid" (Palchak *et al*., 2017) launched by Indian power ministry, co-sponsored by U.S. Agency of International Development (USAID), India is committed to reduce the carbon emission by 40% by increasing electricity production through RES and decreasing fossil fuel based generation. India has set a target to achieve installed power capacity of 100 MW by 2022 from 30 GW in May 2019. Till last decade solar installed capacity was very scattered as

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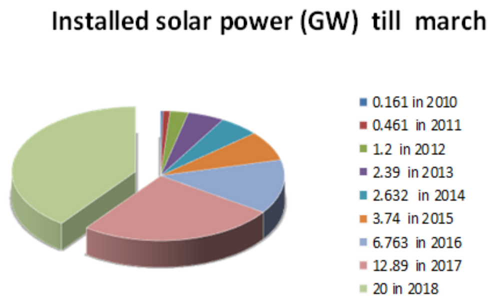

Figure 1. Installed capacity of SECS in India as on March 2018

shown in Figure 1. For efficient gird integration of SECS, several actions need to be taken; such as flexible power generation with distributed as well as conventional sources, Voltage and Frequency (V&F) control, operating reserve, forecasting and scheduling, deviation settlement, equalizing mechanism, data telemetry and communication infrastructures, setting-up of Renewable Energy Management Centers (REMCs), expansion and strengthening of transmission system, and amenability of regulations and standardization in accommodating RES into power generation (Ministry of Power, 2016). A milestone has been laid by India towards this by launching an International Solar Alliance (ISA) cofounded by France in 2015. Over 121 countries rich in solar resource have signed an agreement in ISA summit to exploit more solar power with a vision to reduce dependency on fossil fuel. Indian geographical structure is well suited for solar irradiations and various states have participated in deploying SECS (Kumar, 2015). Andhra Pradesh, Rajasthan, Karnataka, Tamil Nadu, Madhya Pradesh, Gujarat, Himachal Pradesh and Telangana are leading with each having installed over 2 GW solar power plants. Another ambitious project initiated by the Ministry of New and Renewable Energy (MNRE) is Green Energy Corridor (GEC) with a mission to evacuat 20 GW of generation from solar rich states to the deficit ones. The project aims to erect transmission lines of about 9,400 circuit kilometres (ckm) and nearly 19,000 Mega Volt-Amperes (MVA) of substations under INTRA-State Transmission System and 3200 ckm of and 18,000 MVA of substations under INTER-State Transmission System. The distributed nature of SECS attracting the stake holders since it can be closer to end users, thereby reducing transmission losses which have been a big challenge in India. The Government of India (GOI) has asked the central transmission utility to pace-up the amenability of the regulations passed by the Central Electricity Regulatory Commission (CERC).

Installation of solar PV panels to produce bulk power can also be stand alone type such as roof-top installation for self-consumable of power generation. The stand-alone system are installed to meet the local supply demand and to operate as application oriented utility like pump storage system, street lighting, solar heater etc. The stochastic intermittent nature of the Photo-Voltaic (PV) has been taken care by various technological developments like Energy Management System (EMS), Energy Storage Technologies (EST), Power Electronic Converters (PEC). To address Power quality (PQ) issues for making the association with the grid successful four major steps have been adopted by the system operators which includes flexibility in transmission and distribution system, fast-ramping of conventional system to accommodate variable PV generation, data analysis and modelling for better understanding of grid operation and deploying proper power conditioning devices (Beltran *et al.*, 2012). The technological development in PECs have also paid a vital role in bulk installation of on-grid SECS system (Shamim, and Rihan, 2017). Such advancement also has negative impact in energy market when SECS generates excess of electricity. The main cause of such problems is the stochastic behavior of SECS and its fast evolution; hence it becomes necessary for optimal calculation of sizing of the SECS with respect to the capacity of electrical power system. The ultimate goal of the design engineer is to transform the behavior of PV sources from conventional stochastic nature to an advanced system so as to increase its controllability, which can regulate its output power as per the grid parity (Loh *et al.*, 2013). Other important aspects of grid connected SECS is to participate in V&F regulation by controlling Active And Reactive power (P&Q) also to enhance fault ride-through capability during the faults so as to increase system reliability and security.

This paper presents a technological advancement for grid integrated SECS providing comprehensive reviews on various technologies available to meet the grid code requirement. Section II presents the survey on various technologies and main function of the process model to design grid integrated SECS. In section III issues and challenges of grid integrated SECS with some available solutions have been discussed. Section IV presents a survey on available technologies to address PQ issues related to the grid integrated SECS so as to maintain the system reliability and security.

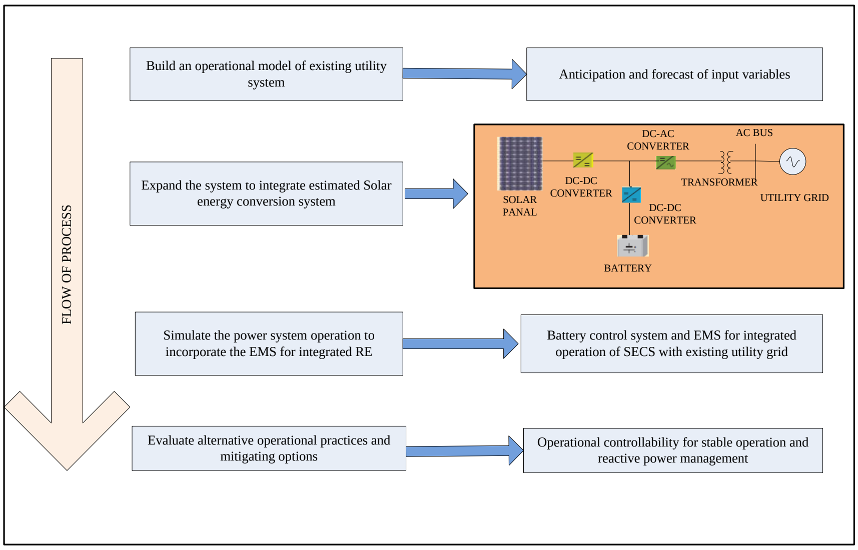

Figure 2. Process model for high penetrated SECS utility system (Riffonneau *et al*., 2011)

Grid Integration of SECS

Large solar plant installation with grid integration is on the rapid rise. For high penetration of Solar, the utility grid needs achievable operational timescale with coexisting conventional generations, counting for intermittent characteristic of the SECS. A report has been released by MNRE in April 2016 for large scale RE integration. This report presents the guidelines about need for balancing conventional and RE generation, PQ, mechanism deviation settlement and related issues. The report features the following along with time bound implementation plan to form a basis for grid management (Awasthi, 2018):

- Regulatory drafts in a manner to manage inter-state deviations.
- Data Forecasting and analysis scheduling.
- Need for appropriate storage.
- Strengthening and restructuring of transmission system
- Ancillary services
- Fast-ramping of conventional system.
- Frequency control
- Deregulated market design
- Power sector Communication
- Capacity enhancement load dispatch centers specially for RE rich states.

As a result of this the GOI have launched GEC as mentioned in the previous section with a road map of (CEA, 2019);

Phase-I (up to December 2020): 20 GW solar and 9 GW wind power projects and, Phase-II (up to December 2021): 30 GW solar and 7.5 GW wind power projects.

For large scale solar integration, proper model as a state of art of cost function is recrudesce, having elements of scheduling, dispatching, operational and market constraints, contingency planning considering generation and curtailment of SECS. Such model quantifies SECS with numerous supervisory controls for optimized scheduling and dispatch. Beginning with the forecast variables (solar data, generation, demand factor, peak load time, tariff) scheduling, dispatch, power balancing and stability are the main control function of the model. Stability here talks about the ability of the system to retain stable operational limits with high SECS penetration to operate under contingency events like, faults, voltage transient relay mal-operation, intermittent RE behavior etc. (Riffonneau *et al*., 2011). Figure 2 delineates the process model to incorporate the deep penetration of SECS into the existing power system structure. The properly controlled SECS also increase the reliability and security aspects of the system. The process model can be seen as the complete supervisory of the operational function and control EMS. For the successful maturation of process model first task is to build an operational model of existing utility system. The simulation model is recrudescing for the power system in which SECS is to be integrated. This step is also termed as the primary level or first layer of the process model in which input variables are identified and generated. These input variables are power from the conventional generator, demand, gap between demand and generation, atmospheric condition for SECS operability, load consumed from RE, storage if any, energy pricing. Anticipation and forecast of input variables are performed in this layer. Solar forecasting is an important tool which assists grid integration of solar by developing better understanding to manage power system balance for secured, economic and reliable operation of the grid (Picault, 2010). In order to engender solar forecasts, diverse resources are required such as weather measurement, satellite data and clouds observations like sky imagery (Ulbricht *et al.*, 2013). Numerical Weather Prediction (NWP) models developed through modern weather forecasting. The best approaches make use of both data and NWP models. After anticipating input function, the second task is to expand the existing power system simulation model to incorporate SECS. In this stage estimated solar energy for meeting the variable load or bridging the demand and generation is integrated with the utility system. For successful operation of grid integrated SECS an efficient EMS is designed, this is the core control and supervisory layer of process model. To account the intermittency of SECS a proper storage system must be designed. This is the main task of the process model since this ensures the continuous operation of grid integrated SECS even when weather condition like solar radiation or heat is not available or varies continuously affecting the performance of SECS and also for the short grid interruption conditions. To design an efficient EMS for grid interactive operation of SECS, an additional EST is required. In literature (Singh *et al.*, 2010) researchers has designed various EST to meet the grid interactive code of SECS. EST requires additional technical constraints which may be designed with in the EMS; this forms the heart of supervisory control for SECS. The last stage of process model is to maintain the operatability of the grid tied SECS at all adverse environmental and system constraints, hence maintaining the security and reliability aspects. The arrangement of dynamic power administrations is not clear as customary PV frameworks are worked with MPPT methodologies (Liu *et al.*, 2014a) to augment the created vitality. Therefore, there are two primary conceivable outcomes for giving dynamic power administrations:

1) the purpose of the PV framework is to save a dynamic energy edge of grid administrations and

2) for having support advances, such as an ESS and selection of proper control strategies for inverter control, as shown in Figure 2.

This aspect of SECS is concerned with maintaining the PQ of the system so as to comply with the grid code requirements and protect the inverter. Inverters are generally designed to operate in what is known as grid 'voltage-following' mode and to disconnect DG when grid voltage is beyond set parameters. When there is voltage sag due to sudden fault or increase in demand, inverters may disconnect while the loads do not. This may lead to threat to the network security causing a brownout or blackout (Miller and Ye, 2003). To avoid this happening, voltage sag tolerances could be broadened and where possible, Low Voltage Ride-through Techniques (LVRT) could be incorporated into inverter design so as to increase the security and reliability of the system. The first choice in meeting the security and reliability aspect of grid tied SECS is to design a proper control strategy for inverter operation, which has been discussed in the next section and second is to incorporate LVRT capability.

The LVRT requirement has been established to ensure reliability of the SECS so as to stay connected to the grid at the time of grid faults. Additionally SECS support the grid during voltage drops by supplying reactive current. Immediately after fault clearance, the active power output must be increased as prescribed within a specified period of time. As per the Central Electricity Authority (CEA, 2013), the voltage drops to about 85 per cent of the nominal voltage for a time of 300 ms, inverter recognises the voltage drop and feeds a reactive current into the system for the duration of the fault in order to support the grid. After the fault is cleared, the active power output is increased as prescribed to the occurrence of the fault within 1 sec. Before a SECS can be connected to the grid, the transmission system operator normally requires a test report or certificate. One of the certification requirements is the measurement of electrical characteristics that includes a test of the LVRT capability. The Central Power Research Institute (CPRI), Bengaluru has requisite test facility.

Issues and Challenges for Grid Integration of SECS

The most refined type of PV application is the execution as micro-grids (MG). In such operability, PV frameworks are joined with other loads and DERs, which can be worked in a controlled, facilitated way either while associated with the principle grid or during islanding (Liu *et al.*, 2014b). The blend of RES and PV frameworks for capacity advances to develop an integrated MG isn't new. The utility of such a blend is mostly applicable to remote areas and specific applications for example, telecomm frameworks, mines, and other were extraction facility not associated with a grid; islanded operation; rural electrification; and portable what's more, strategic applications for military organizations. Be that as it may, now the test is to make it monetarily possible in grid connected applications too. A few factors contributes for such developments, counting for lasting forever solar energy, the rising worry is the controlled operation of DG when operation shifts from interconnected to islanded mode and vice-versa (Loh and Holmes, 2005).

The mass deployment of SECS in conjunction with the utility grid encounters three major challenges (Tongia *et al*., 2018); the first one is fluctuating characteristic of solar energy. This is a major obstacle in meeting estimated energy production with dynamic power demand. A forecasting system is shown in Figure 3 and an efficient EMS which can resolve these problems by deploying EST, but this will add to additional complexity and cost. Control and operational constraints like state of art of charging and discharging function of batteries requisites a central supervisory control which add burden to the EMS (Yazdani *et al*., 2008). Second one is the interfacing of solar power with existing power frame via PEC since output power from solar does not match the grid code requirement and converters helps to match them. PEC/inverters interfacing hinders the operation of power system. The high frequency switching operation injects the harmonics into the system. The output wave form at Point of Common Coupling (PCC) gets distorted, to rectify this additional filters are required. Abundant research (Vandoorn *et al*., 2012) has been reported in literature on filters for harmonic mitigation. C-type passive filter employed for variable loading of non-linear distribution system, an adaptive LCL filter for 5 MW solar system is reported in (Rasul *et al*., 2017) to mitigate switching harmonics. Three-phase (3-Φ) voltage-fed shunt Active Power Filter (APF) in (Yong and Ramachandaramurthy, 2014) is implemented to compensate harmonic effects caused due to non-linear loads by generating reference 3-Φ source current component. In (Bacha *et al*., 2015) performance analysis of compensation behavior of both series and parallel active filter for voltage source generated harmonics and current source generated harmonics are verified. The PQ issues are shown in Figure 4.

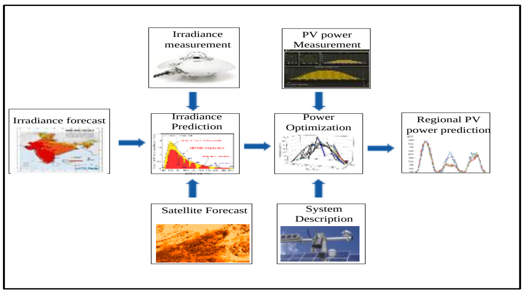

Figure 3. A forecasting system for SECS integrated utility system

Third challenge is the PQ requirement of SECS. The PQ issues of PV system threatens the system stability since they inherently generates power quality issues like V&F regulation, voltage swell/sag, real and reactive power unbalance. According to IEEE definition for power quality "It is the idea of controlling and establishing electronic hardware in a way that is reasonable to the activity of that hardware what's more, good with the start wiring framework and other associated hardware" (Torquato *et al*., 2016) while the International Electro-technical Commission (IEC) characterizes it as "qualities of the frequencies, electric current and voltage, for the defined operating point in an electric power framework, is available addressing PQ issues so as to maintain system stability and reliability. In Mahmud *et al*.,

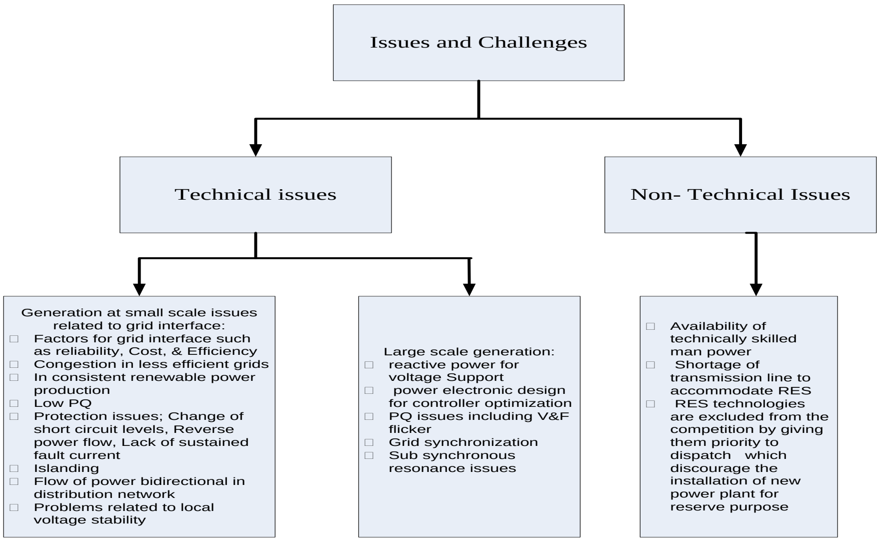

Figure 4. Power quality issues and challenges for grid tied SECS

(2017) PQ is presented as an optimization problem which is formulated using linear programming. An adaptive energy calculator (AEC) is proposed which calculates the super capacitor voltage requirement based on the load connected. AEC improvise the system performance for pulse load by averaging the load current at each pulse, this in turn will optimize the system voltage at transient condition and manages the charging of super capacitors. Multiple objective predictive functions using mixed integer linear programming is optimized in Ryan *et al*., (2001). A communication system is established using smart grid concept which has the access of all the elements of SECS to supervise the Adaptive-EMS (Loh and Pang, 2005). The status of energy storage, load profile, grid power, SECS output, weather forecast and market interpretation all are connected through communication channel to provide supervisory control in rolling window. For deploying large SECS in a grid connected operation the PQ requirement can be met by designing a proper coordinated inverter control (Campanhol, *et al*., 2017). This stage is very much in the research area and, although there are a number of control strategies developed for SECS, the use, coordination and the design philosophy behind this are very much under research and development. These control strategies for inerter design have been reviewed briefly in the next section.

Technological Advancncements in Inverter Design for Improving Power Quality of SECS

As the technology paces with the era, a paradigm shift has been witnessed in the inverter design for SECS leading to the concept of multi-functionality. In the early stage of the development of PV technology, it has been used for electrification of street light, for supplying local demand, for rural electrification, roof-top system, stand-alone commercial power supply system. Since past decade there has been acceleration in penetration of grid connected system forming part of utility system for supplying peak demand including local load in which inverters plays the most important role. The present trend is to use PECs having dual scheme actualizing the following controls (Srinivas *et al.*, 2016).

- Voltage control of parallel converter to create an all-around managed voltage,
- Control the converter in current mode to maintain sinusoidal line current,
- Control the converter as extensive impedance subsequently constraining the line current amid utility voltage limits.

Most of the SECS installed operate as a MG either in conjunction with the utility system or as standalone system. The THD of the MG for both the voltage and the current exceed with those of the main grid and are to be kept low. To control THD for either voltage or current is easy but the simultaneous control is difficult. The cascaded voltage and current controller based converter control technique proposed (Gupta *et al*., 2011) has made it possible. The three phase control MG system is shown in Figure 5. A conventional d-q based Phase-Locked-Loop (PLL) is implemented to provide the phase information required to generate the 3-Φ grid current. PV technology is also being improvised as a FACTS controller like Distributed-STATCOM (DSTATCOM) (Canova *et al.*, 2009). The another application is adaptive-APF, when due to sudden climatic change, high fluctuation solar irradiation or at unavailability of solar power in cloudy weather and night time it is capable of mitigating system harmonic and balance voltages. The system is so improvised such that it is capable of balancing reactive power independent of the real power generated by each lattice of PV. Dual-stage Discrete Fourier Transform based PLL (DS-DFT-PLL) method for Real and reactive Power

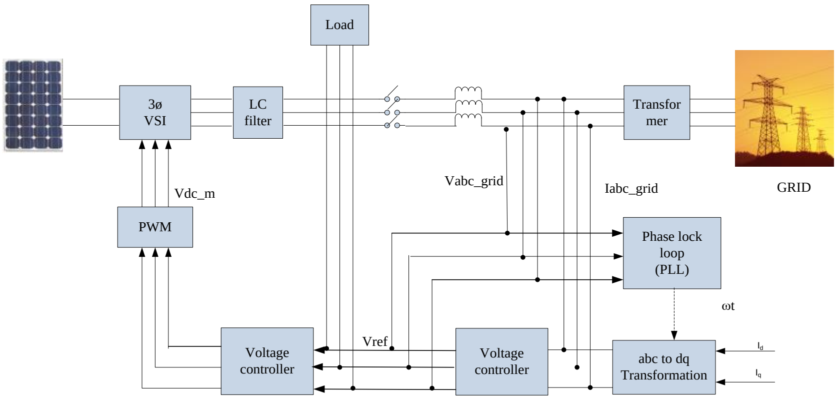

Figure 5. Single line diagram of a grid-connected 3-Φ SECS with the cascaded current-voltage control strategy

Management (RRPM) is proposed in (Liu *et al*., 2010). In first stage fundamental component of phase angle, frequency and amplitude of output signal is extracted using DFT. Grid synchronization the SECS is done in the second stage. The proposed DS-DFT-PLL system limitsthe overvoltage at PCC by storing the reverse power into battery bank. The reactive power demand of the load is supplied through it and successful allocation of the power flow between battery and grid by providing RRPM is done.

In the early years of development of SECS they were just an add-on to the supply system due to the vulnerability of power production characteristics. However, now the scenario largly overcome with the innovative technological advacement. Numerous literature for such systems are sited where unavailability of solar irradiation does not hinder the utility of the SECS into the main stream. A solitary stage 3-Φ four wire grid coupled PV framework, working with a dual-compensating system and feed forward control loop (FFCL) is designed in (Devassy, and Singh, 2015). Other than infusion of dynamic power into the grid, it can also perform the function of Unified Power Quality Conditioner (UPQC), smothering harmonics and compensating RRP. The PV-UPQC depends on a dual compensating strategy (Khadkikar, 2011). The series converter works as a source of sinusoidal current, while the sinusoidal voltage is generated by shunt converter. Therefore, the dynamic reactions of both inverter streams and dc-transport voltage are moved forward. In the dual compensating strategy of PV-UPQC system, parallel converter controls sinusoidal output voltages and series converter controls sinusoidal output currents hence the transition time from VSI to sin at the mode change from islanded to grid is eliminated (Casaro, and Martins, 2010; Varshney *et al.*, 2016). In the proposed system, the contingent on the output power produced by the SECS and the load characteristics, the amplitude of the current drawn and the output power through PEC is governed. Hence, during night or cloudy weather proposed system operates as a classic UPQC system (Fujita and Akagi, 1998) mitigating system harmonics and compensating reactive power demand. In grid-connected SECS, reactive power control and compensation is an important requirement and an essential parameter to maintain the system security and reliability. This is the foremost task of inverters. Table 1 demonstrates the reactive power compensating devices in grid-tied SECS compared with other parameters.

Broadly three theories govern the control structure of inverter namely; dq-control, αβ-control and abc-control. The dq- control also known as decoupled active/reactive power control is realized in the synchronous reference frame by using the abc-dq transformation for converting the grid current and voltages into two vector structure. In this way, the AC current is decoupled into active and reactive power components, I_d and I_q, respectively. The operation of inverter as an APF in order to coordinate the grid operated mode of SECS is designed using d-q theory (Akagi *et al.*, 1983). According to the theory of αβ0 transformation instantaneous P&Q power of the load is calculated in stationary reference frame. This method is also applicable in determining the reference current frame for active filtering (Izhar *et al.*, 2004), for this 3-Φ system is transformed into two phase system using parks transformation. In abc control for each grid current an individual controller is desined hence three controller for three phase system. In abc control, non-linear controllers like hysteresis/dead beat are preferred due to their high dynamics. Their modified design technologies are also applicable as, shunt APF (SAPF), power-monitoring system, SSC, MLI, Dynamic Voltage Regulator (DVR), and UPQC. An insight on the various available APFs, focusing on the weight reduction, economically viable, size, and the reduction in switches of APFs are foreseen in (Tareen *et al.*, 2017). A comparative study for single phase and three phase SECS inverter control and topologies have been showcased in Table 2. Table 3 presents the advantages and limitations of control structures used to design

Table 1. Comparative analysis of different compensating devices for mitigating power quality parameters (Tareen *et al.*, 2017)

Parameters	OLTC	Capacitor and Reactor Bank	APF	DVR	SDBR	STATCOM	SVC	TCSC	UPQC
Reactive power	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes
Active power	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Voltage stability	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes
Voltage Flicker	Yes	Yes	Yes	No	No	Yes	Yes	No	Yes
Harmonic reduction	No	Yes	No	No	No	No	No	No	Yes
Power flow	No	No	No	No	No	No	No	Yes	Yes
Oscillation damping	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes

Table 2. Classification of Grid connected converter topologies

Classification based on utility system	
1-Φ System	
1-Φ two wire system	Full-bridge SPWM (Liu *et al*., 2014b)
	Full-bridge PI (Kuo *et al*., 2001)
	half-bridge SPWM; half-bridge PI (Wu *et al*., 2007)
	Three-leg SPWM ;Three-leg PI (Dannehl *et al*., 2010)
	Dual boost SPWM (Hosseini *et al*., 2009)
	HB ZVS (Half bridge zero VSI) (Shi *et al*., 2013)
1-Φ three wire system	Three-leg SPWM (Lin and Yang, 2005)
	Three-leg PI (Kuo *et al.*, 2003)
3-Φ System	
3-Φ three wire system	Half-bridge SPWM, half-bridge PI (Kang and Liaw, 2001)
	Three-leg SPWM; Three-leg PI (Choi *et al.*, 2012)
3-Φ four wire system	3-Φ four wire shunt/ series converter (Lin and Yang, 2005; Fri *et al*., 2013)
	Full-bridge SPWM (Lindberg, 1995).
	Full-bridge PI (Lin *et al* 2013)
	Split capacitor H-bridge (Loh *et al*., 2007)
	Four leg inverter (Ryan *et al*., 2001)
Multi-level inverter topologies	Neutral point Clamped (Meyer *et al.*, 2005)
	Flying capacitor (Bhumkittipich *et al.*, 2013)
	H-bridge cascaded (Xiao *et al*., 2012 and Newton *et al.*, 1996)
Classification based on modulation techniques and control approach	
Hysteresis	Current controlled PWM (Kazmierkowski and Malesani, 1998)
	Ramp comparison PWM
	Predictive control PWM (Moreno *et al.*, 2009)
Sinusoidal PWM	PR (passive response) (Wang *et al.*, 2011)
	Droop (Vasquez *et al.*, 2009)
	Repetitive (Hornik and Zhong, 2010)
	FLC (Fuzzy logy control) (Gupta *et al*., 2011)
Space vector PWM	PI (Zeng and Chang, 2008)
Classification based on auxiliary services	
Voltage control	APF (active power filter) (Tareen *et al*., 2017)
	RPI (real power injection) (Kim *et al*., 1996)
	UC (unbalanced compensation); PFC (power factor correction) (Kanchev *et al*., 2011)
Current control	DVR (Divyalakshmi and Subramaniam, 2017)
	UPS (Loh *et al*., 2005)
	Harmonic voltage compensation (HVC) (Maissa and Lassâad, 2015).
	Voltage unbalance/interruption/sag/swell compensation (UISWC) (Vandoorn *et al*., 2012)
Voltage-Current control	UPQC (Kumar *et al.*, 2011)
Classification based on the methods of compensation components detection	
FFT-DFT	Frequency domain and time domain approaches (Modesto *et al*., 2015)
Instantaneous power theory (IP)	IP (Akagi *et al.*, 1983)
	FBD (Fryze-Buchholz-Depenbrock) method (Depenbrock, 1993).
Digital filters	Kalman filter (Kamel *et al*., 2012)
	Adaptive filter (Mills-Price *et al*., 2014)
Artificial intelligence	Neural network; PSO based (Kumar *et al.*, 2011)

Table 3. Advantages and disadvantages of control structures for inverters

Control strategies	Associated controller type	Advantages	Disadvantages
dq-control	PI (Partial Integral)	Filtering and controlling can be achieved more easily	Very poor compensation capability of the low-order harmonics
		Simplicity	The steady-state error is not eliminated
$\alpha\beta$-control	PR (Propotional Resonant)	Very high gain around theresonance frequency is achieved	No full control of power factor (PF)Complex Hardware circuit
		The steady-state error is eliminated	
		Highly dynamic	
abc-control	PI	The transfer function is simple	The transfer function is complex
	PR	High dynamic	More complex than hysteresis anddead beat
	Hysteresis	Rapid development	
		Simple control for current regulation	High complexity of the control forcurrent regulation
	Dead beat	Highly dynamic	
		Rapiddevelopment	Implementation in high-frequencymicro-controller

inverter control. Seeing to the importance of inverter and the various functions it performs, a new concept of Multi-Function Multi-Level Inverter (MF-MLI) has been introduced. The MF-MLI is on high demand as the most prominent technology utilized as a part of the SECS grid integrated system. It effectively controls the various grid issues, for example, harmonics in grid current and unbalance alleviation, receptive power pay, control voltage at PCC (Zeng *et al.*, 2013; Wuthikrai *et al*., 2014) and transient process. The MF- MLI topologies are introduced in high-voltage and large PV frameworks in light of its focal points, for example, accurate voltage and frequency regulation, power factor correction, low power dissipation, reduced harmonics and low Electromagnetic Obstruction (EMO) yields and other such factors which helps in maintaining system security and reliability.

Conclusions

The geographical asset of India is favorable for large scale installation of SECS. POWERGRID has formulated Grid Integration Plan for envisaged 100 GW capacity by 2022. The Green Energy Corridor project lead by PGCIL for inter/ intra state transmission will assist the power flow from solar rich states to the other parts of the country and also meet intermittency challenges imposed by SE. Moving towards more centralized regulatory and market policy may efficiently help in integration of more SECS. The security, control, protection, power flows, and earthing of the network was predicated on a centralised generation model which can be enforced into SECS by properly designed inverter control. Inverters should be controlled in a passionate without compromising the reliability and performance of power systems. There have been several important control complexities with SECS for PQ such as grid voltage distortion when there are nonlinear loads providing a balanced neutral for three-phase loads.

In extensive SECS yield control is fluctuating amid the entire day and this power is bolstered to the network and consistently fluctuating control offers ascend to the security worry to the network for making stable matrix. SECS plant proprietor need to introduce the storage element at an extra cost. This storage system has its own issues like charging and discharging which could be managed through proper EMS. At high levels of penetration, at some point, significant changes in inverter design have to accommodate various integration issues. This will probably require significant overall design and performance evaluation in multi-functionality of inverter operation to accommodate coordinated protection and power flow control.

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