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SURVEY

Transmission Network Planning in Super Smart Grids: A Survey

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ABSTRACT For a utility company to reduce CO_2 emissions along with managing load demands, it must strive for a 100 percent renewable electrical power generation. Europe takes initiatives to achieve this goal by developing a super smart grid (SSG) based on renewable energy resources (RERs) by 2050. The SSG is based on two exclusive alternatives: wide area and decentralized power generation using large number of RERs. Before developing such SSG, there is a need to address the critical issues associated with RERs, i.e., load flow balancing and transients stability. Considering a reliability issue involved with RERs and the random deviations between demand response and generation response patterns, load flow balancing and transient stability become challenging research issues in SSGs. These technical issues are also considered to be more challenging, if an unexpected outage in the form of an occurrence of three phase (L-L-L) faults (TPF) arises in SSGs, due to power quality disturbances. To address this problem, load flow balancing probabilistic modeling is performed in this research paper in order to formulate the complexity of randomness between generation and demand response patterns through transmission network planning (TNP) in the form of a super smart node (SSN) transmission network infrastructure. Moreover, a further optimization in SSN transmission network has been done with the addition of a cooperative control strategies in terms of an integrating vehicle to grid (V2G) technology in SSN transmission network in order to achieve further enhancement in load flow balancing and transient stability in SSGs. Furthermore, as SSGs power infrastructure is based on different clusters, therefore in order to accommodate various clusters for load flow balancing, a continuous spinning reserve (CSRs) probabilistic modeling has also been performed in this paper in terms of its integration in SSN transmission network. Considering above probabilistic analysis, future contingencies are easily predictable, before any kind of disruptive changes arises in a SSGs due an occurrence of a TPF. Moreover, from simulation results as performed in this paper, we can easily verified that our proposed probabilistic algorithm of load flow balancing and transients stability outperforms existing literature work and can also achieved near optimal performance, even for a broad range of variations in load and also in case of an arising of significant power quality disturbances in SSGs due to an occurrence of TPF.

INDEX TERMS Super smart grid, renewable energy resources, transmission network planning, continuous spinning reserve.

NOMENCLATURE

SSG	Super Smart Grid.
RERs	Renewable Energy Resources.
TPF	Three Phase Fault.
TNP	Transmission Network Planning.
SSN	Super Smart Node.
V2G	Vehicle to Grid.
CSRs	Continuous Spinning Reserve.
GW	Gigga Watt.
HVDC	High Voltage Direct Curren.
HVAC	High Voltage Alternating Current.

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RIPG	Renewable Integrated Power Grid.
MG	Microgrid.
KW	Kilo Watt.
DRM	Demand Resource Management.
EVs	Electric Vehicles.
SOC	State of charge.
DERs	Distributed Energy Resources.
PFL	Parametric Feedback Linearization.
CPI	Consensus Proportional Integral.
DESS	Distributed Energy Storage Systems.
ESS	Energy Storage System.
WTT	Wind Turbines Tripping.
WT	Wind Turbine.
PG	Power Grid.
MW	Mega Watt.
SAARC	South Asian Association for Regional Cooperation.
VPP	Virtual Power Plants.
CSP	Concentrating Solar Thermal Plants.
FACTS	Flexible AC Transmission System.
DLR	Dynamic Line Rating.
HTS	High Temperature Superconductors.
V2X	Vehicle with Everything.
GWO	Grey Wolf Optimization.
HVDC	High Voltage Direct Current.
IDEA	Improved Differential Evolution algorithm.
PV	Photovoltaic.
PSO	Particle Swarm Optimization.
SSO	Salp Swarm Optimization.
HESS	Hybrid Energy Storage System.
MABO	Modified African Buffalo Optimization.
EMA	Exchange Market Algorithm.
MPPT	Maximum Power Point Tracking.
SQP	Sequential Quadratic Programming.
SIMBO-Q	Swine Influenza Model Based Optimization with Quarantine.
SVCs	Shunt VARs Compensators.
DR	Distributed Network.
AI	Artificial Intelligence.
SHF	Shunt Hybrid Filters.
AFNN	Adaptive Fuzzy Neural Network.
ANN	Artificial Neural Network.
NEA	North East Asia.
ASEAN	Association of Southeast Asian Nations.
AAG	Australian–Asian Grid.
UHVAC	Ultra High Voltage Alternating Current.
V2G	Vehicle to Grid.
PEV	Plug in Electric Vehicle.
AMI	Advanced Metering Infrastructure.
MDN	Modern Distribution Network.
DAO	Dayahead Optimization.
RTO	Real-time Optimization.
FCR	Frequency Containment Reserves.
RFC	RainFlow Counting.
CPDs	Custom Power Devices.
DVR	Dynamic Voltage Restorer.
VSC	s Voltage Source Converters.
LCC	Line Commutated Converters.
BESS	Battery Energy Storage System.
PLF	Probabilistic Load Flow.
EHV	Extra High Voltage.
IoE	Internet of Energy.
MTHVDC	Multi-terminal High Voltage Direct Current.
STA-SMC	Super-twisting Algorithm-Sliding Mode Controller.
VCM	Voltage Control Mode.
CCM	Current Control Mode.
EMSs	Energy management systems.
THD	Total Harmonic Distortion.
ICPT	Inductively Coupled Power Transfer.
EMS	Energy Monitoring System.
CI	Computational Intelligence.
FRCUC	Frequency Risk-Constrained Unit Commitment.
SEIG	Self-excited Induction Generator.
PMSG	Permanent Magnet Synchronous Generator.
SCIM	Squirrel Cage Induction Machine.
MLC	Multi Level Converter.
LFAC	Low Frequency Alternating Current.
K.E	Kinetic Energy.

Symbols

n_c	Normal Operating States of Cluster.
p_c	Power Outage in Cluster.
d_{ek}	Delay in Generalized Clusters.
$\mathrm{G}^f(t)$	Forecasted Generation.
$\mathrm{D}^f(t)$	Forecasted Demand.
$\mathrm{D}^a(t)$	Actual Demand.
$\mathrm{G}^a(t)$	Actual Generation.
$\mathrm{R}_D(t)$	Randomness in Demand Side of Power System.
$\mathrm{R}_G(t)$	Randomness in Supply Side of Power System.
B(t)	Backlogged Demand.
λ	Time Delay.
$r(t)$	Reserve Capacity.
$\mathrm{P}_i(\mathrm{t})$	Actual power.
C(t)	Price Signal.
V(t, E)	Cost function to minimize E with respect to time.
M	Mass of an object.
V	Velocity of an object.
D	Distance.
W	Work.
F	Force applied an object.
A	Acceleration produced an object.
u_f	Final velocity.
u_i	Initial velocity.
P	Power of the wind.
V_a	Velocity of wind.
ρ	density of air.
S	Area covered by wind.

P_r	Active power of the wind.
V_f	Upstream velocity of the wind.
V_i	Downstream velocity of the wind.
w_h	Betz limit.
ω	Angular frequency.
δ_d	duty ratio of converter in d frame.
δ_q	duty ratio of converter in q frame.
E_d	Grid input voltage in d frame.
E_q	Grid input voltage in q frame.
P_{V2G}	Active power from vehicle to grid.
Q_{V2G}	Reactive power from vehicle to grid.

I. INTRODUCTION

Nowadays the importance of electrical energy increases in every field of life therefore the conventional grid is unable to fulfill the requirements of the 21st century. To resolve this issue the concept of super and smart grids have been presented that provide better sensing ability, control mechanism and advanced security and communication system, that support our conventional gird [1], [2], [3]. The super grid is considered as that it supplies power in large scale while smart grid provide power in small scale having decentralization system and both of them are alternative of each other. Nonetheless, we contend that the two ideas complement one another and must operate in as to provide a transfer of energy across various locations. As a result, a SSG [1] and [4] are essential as a power infrastructure to transport electrical energy from various centralised and decentralised generating sites dispersed over a large region with the capacity to handle both fluctuating

RER supply and the periodic variations in demand and supply reaction times. Using RERs in the form of various clusters to fulfil the load demands of different areas and to provide them with cheaper power is one of the fundamental characteristics of SSGs [1], [2]. However, inspite of an achieving cost effectiveness as in case of using RERs in SSGs, there are also number of deficiencies involved with the RERs, and the most significant one is the reliability issue needs to be resolved first so that various regions and the power grid stations that serve them can share an effective and sustainable kind of electrical energy [5]. To offer the best load flow distribution across various areas dispersed over a big area of network, SSGs are built on the interconnection between several RERs arranged in clusters. Second, a widespread [4] roll out of RERs presents wholly novel operational and technological difficulties for the present power infrastructures. However one problem is power quality perturbations, which have a negative impact on power network infrastructure and affect load balancing and peak switching stability. These technical issues associated with RERs need to be properly addressed before developing such huge network of RERs in a form of SSGs. Load flow balancing is a challenging research case in SSG due to its congestion and scalability. Additionally, the reliability involves with RERs, a load flow balancing can be considered as a promising future challenge in SSGs. Things become considerably more difficult when a three phase (L-L-L) fault (TPF) caused by a power quality issue results in an unexpected interruption in SSGs.

A common task in the design and management of power systems is contingency analysis (CA). The system operator provides information on stable security of the power system in line with CA outcomes. However, in terms of voltage instability, conventional CA with corrective action schemes is unable to discern between safe operating conditions and possibly dangerous ones. In reality, one of the primary risks that contribute to the unreliability of the power supply is voltage instability. As a result, an enhanced contingency analysis (ECA) is proposed in paper [6], which extends the traditional CA by include constant voltage analysis based on modal analysis. The research showed the benefits that energy storage and distributed generating resources may provide the stability of voltage, where voltage stability is defined as the capacity of an electric power system to maintain a suitable voltage at all of the grid's buses both during routine operation and after being subjected to disturbances is known as voltage stability [6].

N-1 contingency analysis is one of several features included in energy management systems (EMSs), which are used to regulate how the power system operates. In reality, N-1 contingency analysis is an operation that examines the consequences of a single power network component failure on operational conditions for the power system after the single component has been taken out of the system. In general, computed branch flows are compared with the maximum loading of transformer branches and the current carrying of transmission lines while conducting N-1 contingency analysis, and voltage variations of network nodes are compared with the permissible deviations from nominal values. Since the implementation of the aforementioned N-1 criteria is required by the majority of grid codes, contingency analysis is also applied throughout the design and development stages [7].

Electrochemical conversion is the method through which BESS are able to store energy. When BESS are charged, electrical energy is transformed into chemical energy, which is then transformed back into electricity when the BESS is discharged. BESS allow separate control of active and reactive power supplying into the grid since they include both an energy storage unit and a VSC [8]. The feature of dynamic models, renewable energy, and the dependability of power systems are highlighted in term of cascading failure issues that are now posing concerns. Grid forming technology is the approach to research how renewable energy affects cascade failure because of the new issues that result from the high penetration of renewable energy [9].

From technical perspective, the SSG is the key enabler for the massive integration of RERs in the power system as proposed in [10], [11], [12], and [13]. RERs are widely accessible in outlying areas, especially in European nations. For instance, the best wind locations are those that are offshore or near to the coast [14]. These RERs are not reliable and to a certain degree, they have a variable and an unpredictable generation output. Moreover, these variabilities in different RERs poses an entirely new challenges in terms of its integration with one another as proposed in [15]. Load flow balancing and transients stability are noted as one of the promising problem in this case, which was clearly highlighted in [16]. Considering a realistic scenario of SSG, various topologies have already been studied by different organizations as proposed in [17]. Moreover, environmental organizations [18] should also consider the future SSGs development to be necessary in order to reduce CO2 emissions through maximum penetration of RERs in the existing power grid stations. Projects and concepts based on SSGs have gotten favorable coverage from both the political and media spheres. Although, considering a technical community, a great skepticism exists. The main reason behind this is that,The primary cause of this is the lack of technology that is now available and well suitable for the construction of future SSGs. i.e., technical research at their initial phases. Therefore, detailed simulation studies using appropriate RERs models is essential to be carried out for satisfactory integration of large wind farms in a form of SSGs, before its actual implementation in future. The simulation analysis of load flow balancing and transient stability in future SSGs is the foundation for this research area. Moreover, this research study will not only address these issues in terms of theoretical perspectives, but also in terms of technical perspectives in order to elaborate these issues more clearly in future SSGs.

As discussed previous, that SSG is considered to be a future energy project and European countries are the first one to take initiatives to develop such SSGs [4]. Therefore, the problem formulated in this paper is latest and contrast to all previous ones, as described in the literature, it is new. As a result, the proposed approach for load flow balancing and transients stability in SSGs in this research work cannot be directly compared with the approaches presented in previous literature studies, which is purely based on smart grids. SSG, which is based on different RERs.

Clustering is unsupervised classification approaches that used to recognize the patterns of power usage in a network [19], [20], but in this work clusters are extension of smart gird, having specific electric power comes from renewable energy sources to communicate within SSGs. The following are characteristic of the cluster [21]:

- Clusters have to be reliable;
- Cluster should communicate to linked area having denser region of data space;
- The region in data space that communicate to cluster having some characteristic like convex or linear characteristic;
- A minimal set of variables should be enough to describe the clusters.

To overcome this difficulty, we consider single cluster smart grid RERs approaches for load flow balancing and transients stability and then incorporating it in SSG to show its effects on different clusters of RERs. This shows the deficiencies of utilizing previous proposed algorithms for load flow balancing and transients stability based on smart grids (one cluster approach) in SSGs, which is based on an interconnectivity between various clusters. Moreover, it also shows a significance of our proposed probabilistic algorithms, which is suitable for both case scenarios, i.e., smart grids as well as SSGs, as compared to existing research in the literature, which is only limited to smart grids. Considering a probabilistic modeling for load flow balancing and transients stability in case of smart grids (single cluster), a similar kind of proposed methodology was proposed in [22]. To illustrate that SSG is a transformation of both super grid and smart grid, a three zone strategy for SSG was proposed in [9] as shown in Fig. 1. Both systems could be able to develop with the help of the three zone SSG technology plan while preserving a high degree of consistency. The three zones are super grid, smart grid and the transformation pathways between these two technologies.

A smart grid is a two-way, cyber secure communication system that integrates computational intelligence with electrical energy generation, transmission, substations, distribution, and consumption in order to achieve a free, system that is neat, secure, stable, efficient, and sustainable [23] while Super smart grids are a kind of wide area transmission system that primarily employs renewable energy sources, lowering greenhouse gas emissions while also maintaining the electrical infrastructure of multiple countries. The SSGs allow for two-way communication between sources and loads in numerous countries, and these loads may typically be serviced by a variety of RERs connected to grids [24].

A smart grid may incorporate new energy sources into the system and address intermittent power supply issues, ensuring stability independent of working conditions [25]. The term ‘‘smart grid’’ refers to a system that combines advanced technology, modern sensors, and control techniques [26]. If a need cannot be met by the smart grid environment, the super smart grids (SSGs) is an independent entity that ensures the balance condition between the supply and demand. In other words, it reduces the burden and focuses on a secure, dependable, and sustainable power supply [27]. SSGs are a hybrid system, which combines two or more energy sources. It is possible for this system to combine electric power from different sources with renewable energy sources, either on its own or in conjunction with the recent grid system [28]. Fig. (1) shows relationship between these 3 zones. The zone can be defined as the power network that split into different regions in order to comply with various planning and operating rules for the power system, these regions is known as zones [29].

The methods of transformation between super and smart grids will be effectively eliminated by performing future experiments in the form of SSG in order to developed SSGs infrastructure. At this stage, as super grid and smart grid are considered to be a matured technology, therefore options for SSGs development are widely open. We envision a SSG that plans to resolve the problem of exceeding capacity, by fusing

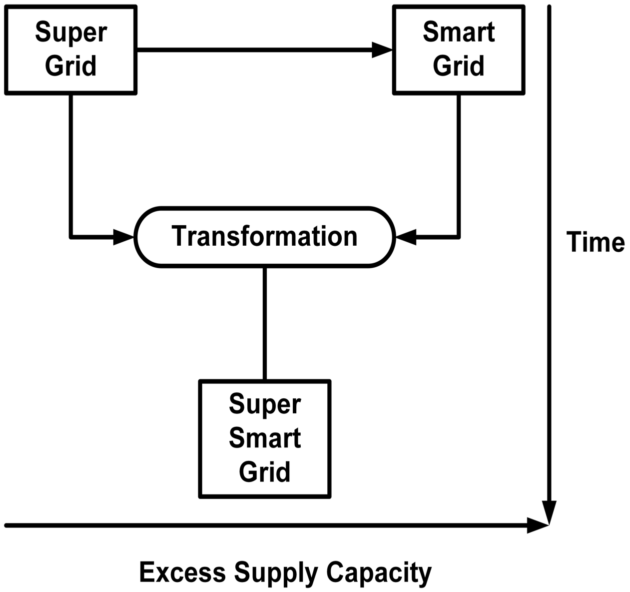


FIGURE 1. A zoning strategy for development of SSGs [13].

the benefits of developed super grid and smart grid technologies, which will most probably be the outcome of zoning.

Now, before discussing the strategies and techniques, that are being used and developed for smart grid load flow balancing and transient stability and then incorporating these in SSGs, the TNP for a SSGs should be properly analyzed in order to address the critical issue of an inter connectivity between various clusters of different regions. To address the variability of RERs for different clusters in SSGs, the TNP will might need an extra levels of fast ramping spinning reserves in order to handle the critical situations that lies in power systems which is caused by unreliable property of the RERs. The severity of the situation is increased by the presence of various contingencies, which make the relationship among deployment and the prime reserve siting, the quantity of load curtailment in the event of using an unreliable RER, the construction of new lines, and the choice and placement of the ideal renewable sites to be established even more difficult. Therefore, in order to reduce these contingencies issues in SSGs, a proactive approach for TNP in SSGs has currently noted an attention of many scientific researchers and power regulating authorities as proposed in [30].

Considering proactive technique, the transmission network planners anticipate the optimum decisions about the generation investments. Moreover, it also helps the transmission network planners in a way, that they may be able to induce generation and transmission expansions with a significant potential benefit to both utilities and customers. Several research works have shown the significance of using a proactive TNP approach as proposed in [31], [32], and [33]. Proactive TNP is a kind of co-optimization technique, that is especially useful in case of large transmission network investments in order to interconnect different regional areas in a form of clusters, i.e., SSGs, with having a large amount of renewable generation potential and with corresponding curtail load demands. These co-optimization techniques for generation and transmission development have been proposed in several research works and technical reports [34], [35], [36], [37]. Considering co-optimization scenario of TNP, it is easily possible for power system operators to easily gain high renewable penetration goals [21], while considering the complex relationship between the new renewable sites with the existing one and their candidate transmission lines. Moreover, the potential of different reserve levels and considering the functioning of power systems in a reliable condition in the existence of huge amount of RERs is also considered to be a timely topic. Clearly, the integration of large amount of RERs as in case of SSGs vary the pattern of power systems operations, and so, it greatly effects the TNP and the minimum reserve sitting in case of SSGs. Furthermore, these RERs are often placed far from load demand network and traditional spinning reservoirs, in a variety of clusters. Therefore, proper TNP commonly impact on the capacity of the power systems to sure the reserve vulnerability, whose significance has also mentioned in [38] and [39].

A V2G can be able to control the power system during disruptions in the quality of the power and quickly stabilize the whole power system. In case of fault in SSGs, V2G provides a high quality of power with a minimum time because it includes a battery management system that gives faster energy with low value of transient and balancing the flow of power [40].

The V2G technology implies that the interaction of electric vehicle with grid. If grid is unable to fulfill the requirements of the load, then energy flow from vehicle to grid while in case of excess of energy to the grid then power flow from grid to electric vehicle [41]. For real time communication it must be necessary to involve the status of charge and demand of load for better operation of V2G mode [42]. Therefore, the primary activity in vehicle-to-grid really consists of the two-way exchange of information and energy between EVs and the grid [43]. The vehicle to grid system must guarantee that an adequate number of EVs are available as energy storage resources within a certain amount of time in order to fulfill the needs of power load management. The specific number of EVs must be combined through an aggregator, and track the associated data of the EVs, such as the position of the EVs, the state of charge of the batteries, the planned departure time, and the real-time battery capacity chargeable and dischargeable, etc. so that the control center can effectively plan the load requirements of the grid based on the EVs charge and discharge. The aggregators can be ordered to deliver vehicle-to-grid services by the smart grid control center in order to give the smart grid feedback-related data.

Simultaneously aggregators provide the gathered information to the control center. The control center may now track the user's locations and examine the users private information if the original location data has been provided [44].

Different options are available for transmission network upgrade using TNP proactive approach in SSGs. One possibility is using local reinforcements to strengthen the network. Large power transfers need greater transmission capacity, hence it is important that these reinforcements take place throughout the chosen transmission channel at numerous places. Installing direct transmission lines close to important generating and demand site in the shape of a grid, sometimes known as a "Super grid," as suggested in [45], is another potential proactive strategy of TNP. HVDC or HVAC technology may be used to build such transmission lines. In this research work, an equalized power sharing between different power grid stations of their corresponding clusters is proposed using both TNP proactive approach, i.e., local reinforcement and direct transmission line, which provides load flow balancing and resolves the future contingencies issues in SSGs. Local reinforcement approach is utilized inside a cluster to strengthen the transmission inter connectivity of different RERs, whereas direct transmission line approach is utilized for cluster to cluster interconnection in order to supply an effective load flow sharing between different clusters. By providing an equalize power sharing among various clusters of SSGs through TNP, it guarantees that not every cluster's component will experience an early energy shortage, so the full power capacity of all clusters in SSGs is available to regulate each other.

Equalize power sharing between different power grid stations and their corresponding clusters in SSGs is technically and economically preferred due to the following reasons as proposed in [46]:

1) Elimination of the circulating currents among transmission lines and relief overloading conditions of different power grid stations of various clusters in SSGs.
2) Better utilization of the local energy resources in SSGs at the receiving side of different power grid stations,
3) Equal revenue distribution among investors and owners of various clusters and local energy resources located at different regions of SSGs.

Now, in order to address various strategies and methodologies that have already been studied for load flow balancing and transient stability in case of smart grids, many proposals have already been discussed in [47], [48], [49], [50], [51], and [52]. The techniques related to load flow balancing can be further categorized into different sections. These approaches optimize an issue of load flow balancing with the help of a storage and flexible loads in a RIPG as proposed in [28]. Considering a dynamic optimal framework for flow of power for multiple time periods to represent load curtailment issues of distributed generation resources based on renewable, an optimum solution based on an energy storage systems and flexible demands was already discussed in [29]. Similarly, in case of load flow balancing, another approach is proposed in [30] to balance the power generation of the RERs in order to maximize or minimize the usage of power in the microgrid (MG) through controlling a stored energy. Recently, different probabilistic approaches are also studied in the literature by considering issue of uncertainty, which exist with the RERs. It includes designing of a probabilistic and also an optimum power flow algorithms in order to mitigate an issue of uncertainties, which occurred due to an effect of an environmental impact on generation resources based on PV and wind farms as proposed in [50], [51], and [52].

Now, in order to incorporate these techniques in SSGs for load flow balancing to show its effects on different clusters, we must first clarify a technical question, that is it suitable to incorporate these smart grids load flow balancing approaches in SSGs By answering this question, we must first consider the common drawback involves in above listed techniques. The main limitation in proposed approaches is that, all of these load flow balancing techniques required flexible loads, control mechanisms and also sophisticated storage by concerning optimum flow of energy to the load receiving station of different power grid stations. Additionally, these recommended techniques are thought to be computationally demanding, and the best load flow balancing solution is not always assured, if we considered a larger deviation between loads on the receiving station (KW) of different power grid stations (MW), which is the main reason behind developing a future SSG infrastructure. In order to tackle this problem, in this article, a new approach to solving this issue is presented; a super smart node (SSN) transmission network topology using TNP proactive approach, that interconnects various RERs with one another in an intelligent way for enabling load flow balancing in SSGs while taking variable heavy loads into consideration. This is believed to be the first piece of work that discusses the process of developing a specialised SSN, and to the greatest of our understanding, in case to provide synchronous stability to the power system in terms of load flow balancing on the receiving side of different power grid stations, even in case of an occurrence of TPF in SSGs.

The SSN is basically a transmission network technique that emerge various transmission networks in an intelligent way, so that these transmission networks must be able to takes into account different uncertainties, that happen in power system network caused by variations in loads and RERs, especially TPF event in SSGs and improvised the balancing of the receiving side load flow, subjected to different potential vulnerabilities in SSGs. It contains both types of nodes, IT node is responsible for flow of information while electrical node is responsible for flow of electricity. The Fig. 2 shows the combining working of both electrical and IT nodes via different entities [53].

Moreover, this SSN transmission network topology for load flow balancing should be effectively utilized in both smart grids as proposed in [22] and SSGs power infrastructure as compared to previous proposed approaches in literature for load flow balancing, which is only limited to smart grids.

Similarly due to congestion issues in SSGs, further variations in terms of load flow arises on the receiving side of different power grid station, especially considering an

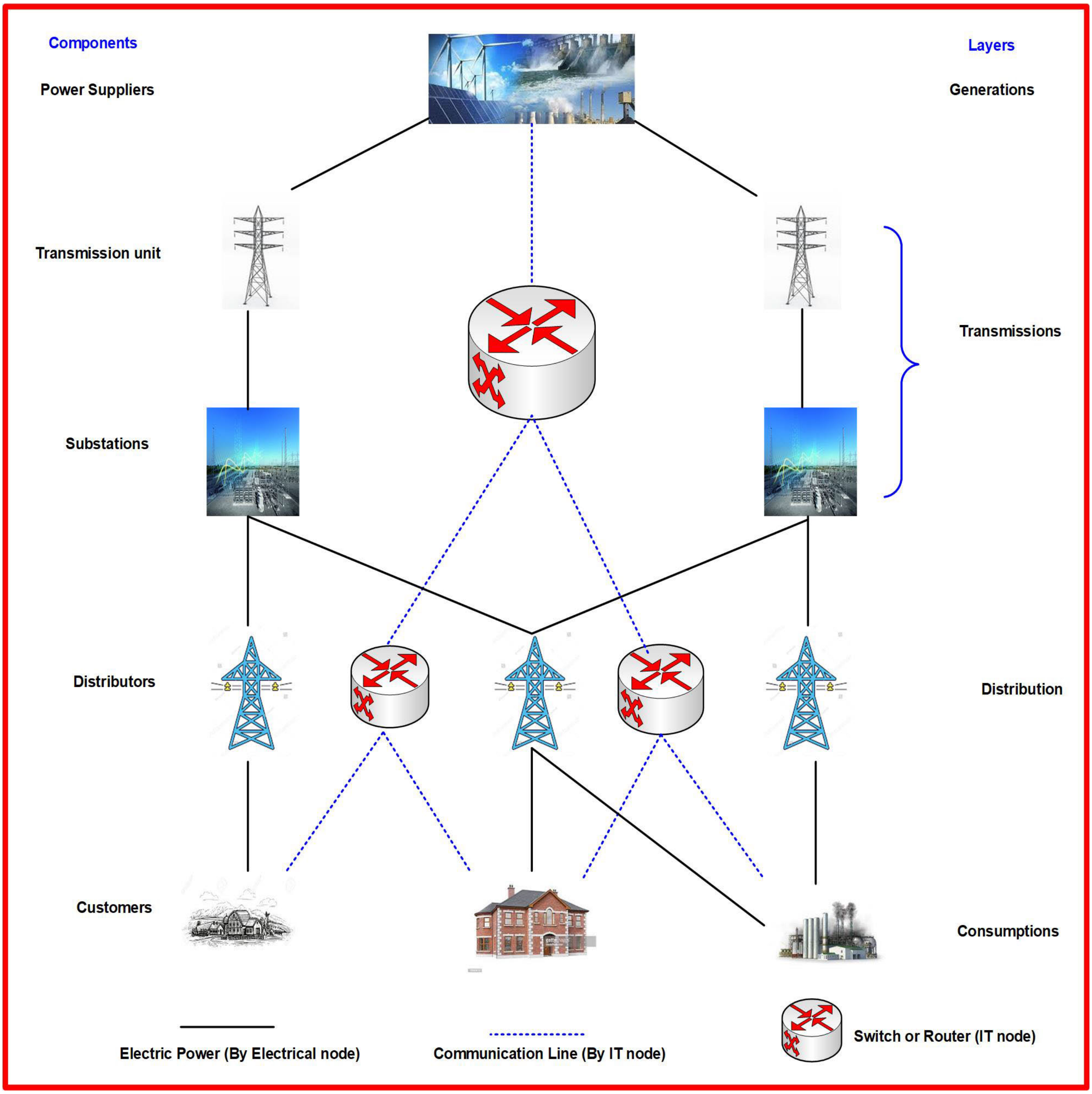


FIGURE 2. The combine function electrical and IT nodes in SSGs system.

occurrence of TPF with corresponding larger delay, which causes the tripping of different wind turbines nearest to the fault location. Therefore, the receiving side of various power grid stations in various clusters may easily be improved further in terms of load flow management and transient stability, by providing a cooperative control strategy in terms of an integrating V2G technology in SSN transmission network of SSGs.

There are different cooperative control techniques available, however, a major of them can be divide into three different group. The first technique is based on a centralized control scheme by utilizing a central controller in power system which analysis all energy storage systems as proposed in [54] and [55]. As suggested in [56], this sort of approach involves communication connections between the centralized unit and each and every part of the power systems in order to gather data on a global scale and analyze it before sending it to the controller. Thus, this technique is not a cost effective option and it is also vulnerable to a single point failures, due to which it cannot be utilized in SSGs, as single point failure causes a destructive effect in a form of cascading failures in SSGs. The second technique is fully based on a decentralized control scheme, which consider local information only, like droop control as mentioned in [57]. This type of cooperative control technique is less expensive and it is also robust when communication medium is not essential. Although inspite of this advantage, there is still an issue of an absence of a vast amount of an available information. Therefore this technique may not be effective at all, especially if we intend to use every resource in the electricity network as effectively as possible, as suggested in [58]. The third method relies on a distributed control strategy and merely calls for information sharing between power system components over a local communication network. In order to make the power infrastructure of an SSG economically viable, these administrative and control solutions must be effective for the SSG's power infrastructure due to the potential diversity and distribution of its components. According to the theory put forth in [56], distributed control strategies that have been optimized and well designed are flexible, efficient, scalable, and inexpensive to implement. For these reasons, these techniques are seen as a promising alternative for offering the best control for load flow balancing in SSGs. In order to manage the charge of the battery packs linked to it and use the power capability to handle various clusters of SSGs, especially in those case scenarios where a power quality disturbance issue occurs in SSGs due to an occurrence of TPF, we provide such a distributed supportive control schemes using V2G.

The SSN transmission network in our case scenario will only improvise the SSGs for load flow balancing, whereas, V2G is regarded as a useful technology, both for load flow balancing and transients stability in SSGs. Moreover, considering from literature point of view, a V2G importance for DRM in smart grid was already proposed in many literature studies, but it's utilization for load flow balancing and transients stability analysis in case of SSGs is not discussed in literature. Before discussing, that why V2G techniques as already proposed in literature for smart grids is not suitable for SSGs, as compared to our probabilistic V2G proposed approach, which is suitable for both smart and SSGs power infrastructure, some of these V2G techniques for DRM should be properly addressed.

For DRM employing V2G in the context of smart grids, numerous approaches and algorithms have previously been addressed. These DRM methods may also be decomposed into other groups. For instance, in [59] suggested an optimization technique based on DRM to stabilise an entire power network employing PV inverters and EV chargers. In [60] and [61], researcher suggested to use an implementation of renewable energy resources relying on PV and wind turbines to address the issue that EVs experience due to their inconsistent charging and discharging behavior. In [62], it has been observed that the load profile may be shaped using DRM to balance both demand and supply of energy. The author offered a solution in [63] for scheduling electricity generation in accordance with engagement plans created by the consumers using DRM. Moreover, a game theoretic strategy incorporating DRM was used in [64], [65], and [66], to take into account the advantages of both consumers and utility. Similarly, in order to control the household appliances energy utilization through shaping of a load profile and also to reduce an electrical energy cost in considerations of residential grid, the scholars resolved this issue in intelligent way using DRM in [67] and [68]. Moreover, due to technological advancement in terms of the Internet of vehicle [69], [70], [71] and vehicular ccloud [72], [73], [74], Real time flexible DRM is made possible for EVs via V2G technology. In [75], it has proposed to investigate how EV mobility can affect DRM in V2G systems in smart grids.

Moreover, in DRM using EVs technology, various approaches have been considered for charging and discharging mechanism of EVs. In [76], the author proposed a solution in terms of analyzing the DRM performance during an off peak charging of an EVs. Employment of dynamic pricing in order to control the EVs users charging and discharging behaviors using DRM was proposed in [77]. Moreover, satisfying EV charging demand from electricity generation due to wind power and photo voltaic power using DRM was proposed in [78] and [79]. Analyzing the control of V2G on battery SOC has presented in [80] in order to obtain regulation of frequency for power grid stations and EV charging using DRM techniques. Additionally, to enhance the performance of DRM in smart grids, many topologies have been considered in literatures, i.e., the profit of EVs users in terms of DRM was proposed iin [81]. Analyzing the effect of DRM on various costs of power grid stations was proposed in [57] and [82]. Moreover, the concept of fairness, in terms of power delivery by utility and power consumption by customers using DRM schedule was also proposed in [83]. Considering all of these techniques, power in the region grids will be addressed by V2G technology, which have a significant contribution in the ancillary services sector, i.e., one cluster (smart grid) constant stabilization required to balance supply and demand. whereas, addressing of V2G technique for load flow balancing in multiple regional power grid stations in a form of SSGs is absent in literature. Therefore, in order to make these V2G techniques in smart girds to be effectively utilized for load flow balancing in SSGs. There is a need to redesign a transmission network for one cluster and transformed it into for various clusters in order to provide an effective load flow sharing between different clusters. This can be done through TNP proactive approach, i.e., developing a SSN transmission network topology as previously discussed. According to the researcher opinion, the proposed work is a new that explored the issue of load flow balancing using V2G cooperative control strategies in SSGs, for balancing the power system on the receiving side of different clusters, even in case of an occurrence of TPF with corresponding larger delay in SSGs.

Similarly, V2G is also considered to be a valuable resource for transient stability analysis in smart grids, i.e., upto one clusters. However, its utilization in terms of transient stability in case of SSGs, i.e., cluster to cluster interconnections is not discussed in literature. Various strategies have been proposed for transient stability analysis using V2G in case of smart grids in [84], [85], [86], [87], [88], [89], and [90]. These techniques can be further divided into different categories. Transient stability analysis in terms of reactive power compensation in smart grids using V2G was proposed in [64]. Active power regulation in terms of load flow balancing by valley filling technique using V2G was proposed in [65]. Moreover, transient stability analysis for current harmonic filtering; in order to supply ancillary facility, by considering frequency control using V2G technology was proposed in [66], [67], [68], and [69]. Similarly, enhancing grid efficiency for maintaining stability in power system using V2G was proposed in [70].

Nowadays, incorporating EVs into power grids allows them to serve as energy storage and power generating units in addition to serving as charging loads [91]. V2G may also be regarded as a useful resource to engage in grid ancillary services to preserve the safety and reliability of power grids, like frequency control [92], voltage management [93], spinning reserve [94], and load peak changing [43]. Nevertheless, one EV cannot engage in these grid ancillary services because to its limited capacity. In order to regulate a large number of EVs and offer grid ancillary services, the model of a V2G aggregator has presented in [95]. All of these techniques provide an effective solution in terms of transient stability analysis using V2G in case of smart grids. However, the utilization of V2G for transient stability analysis due to power quality disturbances in case of an occurrence of TPF in SSGs is not discussed in literature. As, in case of SSGs, due to inter-connection between different RERs clusters and considering the reliability issues involve with RERs, transients stability should be consider to be a challenging research issue in SSGs.

Moreover, inspite of utilizing distributed based V2G cooperative control strategies in SSGs to enhance transients stability of the power system. we can also utilize other distributed controller based methods to control many DERs in SSGs in order to enhance transients stability of the power systems. However, a major drawback of utilizing these distributed controller based approach in SSGs is that, it will adds a significant delay in a power systems. Before discussing certain drawbacks involves in case of utilizing other distributed controller based approaches in SSGs, some of these controller based techniques to enhance transients stability in power system should be properly addressed.

Recently, several distributed controller based techniques in Fig. 3 have also been employed in a control loop for the enhancement of the transient stability of power systems. A transient stability enhancement in terms of distributed controller by using flocking theory was proposed in [96]. Although, the results obtained from simulation is represented in [77] show that controller operations may be steady as transients delay large due to the power quality issues in power systems.Farraj et al. [97] operate rapidly energy storage devices to swiftly balancing the grid using a PFL approach inside a distributed controller architecture. The flocking based controller in [96] and the CPI controller as described in [98], [99], [100], [101], and [102] have mathematically compared to the suggested PFL controller. The PFL controller gave a more significant result as compared to flocking and CPI controller in terms of transients stability enhancement by reducing the corresponding delay issues in power systems. The PFL controller's flaw is that, as a consequence of using Kron's technique, which was suggested in [103], for system reduction, it implied that all generating angles and voltages were known, which was essentially incompatible with the idea of a distributed method. Therefore, a distributed nonlinear robust controller has suggested in [104], which resolves the above issue in PFL controller and achieve the transient stability enhancement of power system within around 3s with the delay in a power system corresponds to 400ms. The suggested controller in [78] and the PFL controller both accomplished identical performances, when the time of delay is 50ms in case of transients, while for other cases it fails. All of these proposed distributed based controllers approaches provides an effective approach in terms of enhancing transient stability in power systems, but considering the delay up to small scale, i.e., 50ms - 400ms. Therefore, there is a need to operate the fast acting energy storage systems in such a way, that they can compensate for time delays due to transients issues and input, while the addition uncertain load along with varying time disturbance also considered, such as in case of SSGs. Our approach is that, to manage different fast acting DESS in SSGs, new distributed controller-based methods have been developed, we utilized the concept of distributed cooperative control strategies using only one ESS, i.e., V2G. V2G employs an energy storage device that reacts swiftly to stabilize the power grid in a small interval amount of time, due to the occurrence of TPF, even with the improvement of appropriate delay in parameters of transient conditions in a power system. The simulation results have been created based on data of observation and in terms of comparison analysis between our propose V2G distributed cooperative control approach with the previous distributed based proposed controller approach in [85] in order to show effectiveness of V2G cooperative control strategies in SSGs. Moreover, considering the phenomena of TPF occur in SSGs, a similar kind of proposed technique for stabilizing of load flow and analysis of stability in term of switching peak in SSGs with the help of V2G technology has discussed in [22].

Moreover, in this research work, we studied the factors that affect the quality of power under disturbances, i.e., transients on SSGs that occurred due to transients stability issues, which arise in power system caused by TPF that happen in SSGs. Although transients stability is a term, that is used especially for an angle stability in power system literature, as in case of an occurrence of larger disturbances in power systems, whereas, power quality disturbances is a term that is especially reserved for voltage sag and swell, transients, interruption, voltage fluctuations, waveform distortion, and variations in frequency, but the relationship between these two terminologies is very effective, means both of these terminologies are interlinked with one another as proposed in [105] and [15]. Transient stability can be elaborated in the power system to cater the synchronous stability in power system network, when it is tested in the existence of unbounded disturbance, i.e., as in our case phenomena of TPF event with corresponding larger delay in SSGs. These disturbances have a severe impact on power system network and it can also cause a enough abnormality in wind turbine generator rotor angles in a form of large excursion, which observe a enough variations in the speed and position of the rotor. as a consequence of these variations, a serious power quality problem, i.e., transients arise in SSGs. The oscillations caused by transient stability problems in a power system network, as well as in the event of the occurrence of many kinds of faults that occurs in a power system network, are regarded to be a serious problem for power system stability, and they should be managed as such. These transient stability oscillations are explored in this article from the perspective of power quality. It is argued in this research that transient stability fluctuations in a power system network may cause the development of serious power quality perturbations, or transients in power systems, as in the case of SSGs power infrastructure. This study describes the transient stability problems in power systems proposing both numerical and conceptual studies, which define a number of power quality phenomena that may be driven on by the oscillations in transient stability as suggested in [87], and [15]. Contrary to the widely held empirical presumption that these both issues (stability of the power system along with production of quality power) are unrelated to one another, the simulation results from [87], and [15] clearly demonstrate that transients stability oscillation caused by an TPF that happen in a power system infrastructure in fact it can a vital role for the arises a disturbance which led to power quality issue, i.e., transients that occur in the power grid stations at receiving side.

As V2G provides an effective solution for the analysis of both load flow and transient stability, but up to its small scale utilization, i.e., as we don't have an enough EVs available in order to provide large scale backup to multi power grid stations of various clusters in SSGs. Therefore, to study the problem of larger power outages in SSGs, due to an occurrence of TPF with corresponding larger delay, which causes a tripping of wind turbines nearest to fault locations, a non-cooperative control based probabilistic model of CSRs has also been formulated in SSGs in terms of its integrations in SSN transmission network. CSRs non-cooperative control based probabilistic model mainly optimizes the SSGs for the balancing of load flow but the effect of transients due to an occurrence of TPF in SSGs is still there. Therefore, the above simulation results between V2G distributed based cooperative control and the proposed distributed controller based approach in [85] for transients stability is further verified in terms of comparison analysis of probabilistic modeling of V2G cooperate control based technique and CSRs non-cooperative control based technique in order to show effectiveness of V2G in terms of compensating transient stability issues in SSGs. The difference between cooperative and non-cooperative control was clearly formulated in [36] and [106]. In the case of cooperative control in a power system, each subsystem is conscious of the dynamic model of the other subsystem in order to forecast future choices more precisely, particularly in the event of concerns with power quality disruptions that happen in power systems as a consequence of the occurrence of various types of faults. Our V2G based cooperative control probabilistic model for SSGs power infrastructure utilizes the same approach for effectively reducing the issue of transients stability under the event of TPF in SSGs. Whereas, for non-cooperative control based approach the transmission of information in order to communicate between different subsystems is limited. Therefore, compromises on an accuracy has been made in case of predicting an accurate future decisions for power systems. This shows the effectiveness of cooperative control based V2G approach as compared to CSRs non-cooperative control based approach for reducing future contingencies issues in a form of load flow balancing and transients stabilities in SSGs. The proposed work that discusses the evaluation based on load flow balancing probabilistic modelling in order to describe the complex nature of randomness between generation and demand response behavior through an SSN, CSRs, and V2G, and transients stability probabilistic modeling through only V2G in SSGs, even under consideration of TPF. The novelty of proposed work is mentioned in below points:

1) A qualitative overview of major enabling technologies for smart grids is explored that used in SSGs. Additionally, the challenging tasks related to the implementation of smart grid technologies in SSGs have been explained for its smooth operation.
2) The TNP proactive method is used to design a customized SSN transmission network, compensating for any interruptions in the form of TPF with correspondingly smaller delays as load flow balancing on the receiving side of various power grid stations in SSGs.
3) The concept of cooperative V2G control technique along with other non-cooperative techniques can be implemented in SSN transmission in case of TPF event with corresponding larger delay due to which causes tripping of wind turbine that linked with cluster near the fault location. As a result, SSGs will be optimized for load flow distribution between different clusters, and transient stability problems also be reduced.
4) A probabilistic model is used to express the complexity of randomness in terms of load flow balancing in the SSN transmission network, CSRs, and V2G, as well as the analysis of transient stability via V2G topology.

5) In order to demonstrate the effectiveness of the V2G cooperative controller-based approach in order to reduce the transient stability issues in SSGs with the corresponding improvement in time delay due to an occurrence of TPF in SSGs, a comparative analysis between V2G cooperative control-based technique, CSRs non-cooperative controller-based technique, and distributed non-linear robust controller-based technique have been carried out in [104].

The rest of the article is split into the sections that follow: The methodological portion is mentioned in Section II. Section III includes the result generated from the simulation for comparison purpose of the proposed technique with current load flow balancing and transient stability models. Section IV provides a brief survey about countries moving towards developing future SSGs. Section V illustrates about the risks and open questions raises in case of development of future SSGs. Section VI gives a brief overview of technological uncertainties during development of future SSGs. Section VII provides an overview of an infrastructure of European SSGs. Finally, Sections VIII, IX and X include the conclusion and future work.

II. METHODOLOGY

The suggested technique is categorized into two sections. Initially, the level of power system vulnerability is assessed in the event of a TPF in SSGs, which are made up of four clusters and twelve RERs. The study of an uncertainty approach depends on three phase (L-L-L) faults delay is presented to distinguish the phenomena of occurrence of TPF with associated smaller or greater delay in a power system in order to research power system vulnerability assessment. Furthermore, challenges with power quality caused by the occurrence of TPF in SSGs and irregularity of load flow caused by specific RERs tripping are also taken into account. A power system may be vulnerable to TPF if the delay is either smaller or bigger, i.e., fault occurrence interval time, then Algorithm 1 or Algorithm 2 uses the SSN, CSRs and V2G scenario to use probabilistic modelling to examine and anticipate the predicted irregularity in a power system.

We considered the generic case because the concept of SSGs has not simulated and implemented yet in real life scenario. It will be implemented in particle life in future 2050 [4]. Therefore, we consider these two duration for the delay as per choice to implement the algorithm 1 and algorithm 2 for 0.01s and 0.1s respectively. The flow chart for implementing of algorithm 1 and 2 are represented in Figs. (4) and (5) respectively.

Algorithm 1 uses SSN solution to detect and compensate smaller delay that occurred in the form of TPF, with no tripping of wind turbines. Whereas Algorithm 2 uses SSN, CSRs and V2G as a solution to detect and compensate larger delay caused by TPF, that occurred. i.e., tripping of wind turbines of cluster 1.

Secondly, Algorithm 2 is used in order to provide transients stability enhancement in SSGs with the help of probabilistic modeling, such as an occurrence of TPF in cluster 1 with corresponding larger delay, a choice on the switching of V2G on the receiving side of cluster 3 is executed to compensate transients stability issues in cluster 3 of SSGs. SSN are functioned at the receiving end in both cases, i.e., occurrence of TPF with equivalently shorter or longer intervals, which causes a different variation in d_{ek} parameter, i.e., greater than predefined threshold of 0.01s, which make the potential vulnerability that depends on the event of TPF with corresponding shorter or longer delay in power systems. For TPF with smaller delay, which doesn't cause the tripping of wind turbines as mention in Algorithm 1, i.e., $d_{e1} = d_{e1} + d_{e1+0.01s}$, $d_{e2} = d_{e2} + d_{e2+0.01s}$, $d_{e3} = d_{e3} + d_{e3+0.01s}$ and $d_{e4} = d_{e4} + d_{e4+0.01s}$ of corresponding four clusters, only SSN is operated. Whereas, if delay parameter d_{ek} is greater than approximate range of threshold, i.e., 0.01s, considering a larger delay due to an occurrence of TPF in cluster 1 as mention in Algorithm 2, i.e., $d_{e1} = d_{e1} + d_{e1+0.1s}$, $d_{e2} = d_{e2} + d_{e2+0.1s}$, $d_{e3} = d_{e3} + d_{e3+0.1s}$ and $d_{e4} = d_{e4} + d_{e4+0.1s}$, it initiates the next transition stage $tcj + 1$. Furthermore, in order to fully optimize the SSG for load flow balancing and transient stability, a choice on the switching of CSR 1, CSR 2, V2G, and CSR 3 in the SSN transmission network is required. CSR 1, CSR 2 and CSR 3 only optimizes SSG for load flow balancing, i.e., compensating power drops issues of cluster 1 $(n_{c1} - p_{c1})$, cluster 2 $(n_{c2} - p_{c2})$ and cluster 3 $(n_{c3} - p_{c3})$, whereas V2G is considered to be a precious resource, both for optimizing load flow stability and reducing transients stability problems in SSGs, i.e., compensating cluster 3 power drop issues $(n_{c3} - p_{c3})$ as well as compensating the transients delay $d_{e3} = d_{e3} + d_{e3+0.1s}$, which arises due to transients stability task under consideration of an occurrence of TPF with corresponding larger delay in SSGs.

The closed loop control system demand response probabilistic model for optimizing the stability of both load flow along with enhancement of transient stability in SSGs is shown in Fig. 3. With a closed loop control system power network in the existence of an SSN, CSRs, and V2G as illustrated in Fig. 3, the constantly monitoring have been readily conducted in SSGs for balancing of load flow analysis and transients stability improvement. By considering the probabilistic model which is closed-loop represented in Fig. 3, power system operators can quickly consider the necessary corrective action to improve transient stability and offer the best load flow balance, particularly when TPF occurs in SSGs. When TPF occurs in SSGs with a smaller corresponding delay, SSN effectively enhanced the power system for the balancing analysis of load flow. However, when TPF occurs in SSGs with a larger corresponding delay, which trips the wind turbines closest to the fault location, switching of an already integrated CSR and V2G in SSN transmission network is required to completely optimize the power system for load flow balancing and transients stability. The concepts

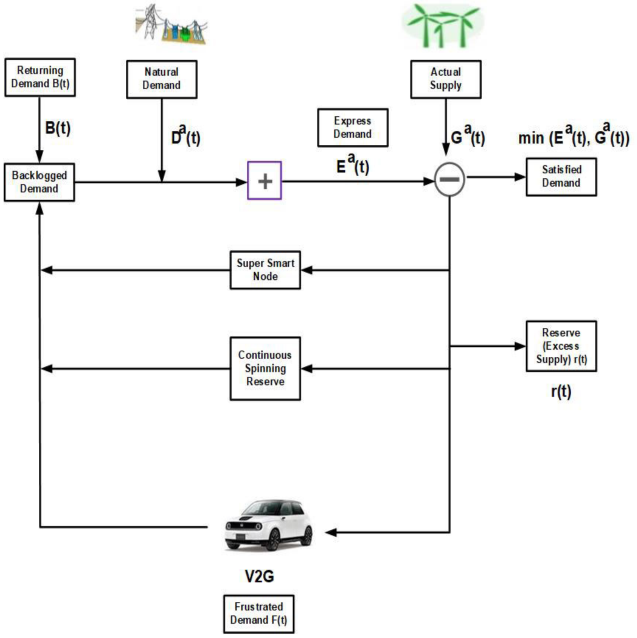


FIGURE 3. **Demand response schematic model for SSGs.**

implemented in Fig. 3 are explained in further description in the next part of the paper.

A. SUPER SMART NODE TRANSMISSION NETWORK PLANNING PROBABILISTIC MODELING

The optimal generations from RERs will be determined using the suggested RERs probabilistic TNP model of the SSN transmission infrastructure, taking contingencies evaluation in SSGs into account, as well as power quality issues cause by TPF that occurred in SSGs, while also ensuring spinning reserve deliverability. Considering these power quality disturbances due to an occurrence of TPF in a synchronized complex network of four clusters with every one which consist of three RERs in a form of SSGs, a load flow balancing problem using TNP proactive approach is investigated by using the concept of SSN transmission network. Through designing of SSN transmission network by using TNP proactive approach, we can actually adjust our forecasted supply, i.e., $G^f(t)$ in the context of our forecasted demands, i.e., $D^f(t)$ reducing the needs and expectations in SSGs i.e., $F(t)$ as represented in Fig. 3. For achieving this objective, a transmission grid closed loop control system model is formed which depicts in Fig. 3, by considering a larger penetration in:

1) Demand Response, and
2) Power quality disturbances.

A similar kind of proposed work in order to provide sustainability of an elastic demands in case of smart grids was clearly formulated in [107]. Moreover, in our case the penetrations in demand response patterns occurred caused by the tripping of the RERs with an occurrence of TPF with corresponding

Algorithm 1

```
Input  : A group of normal operating states of different clusters in SSG
         $(n_{c_1}, n_{c_2}, \ldots\ldots, n_{c_n})$,
\\ $n_{c_1}, n_{c_2}, n_{c_3}, n_{c_4}$, corresponds to normal operating states of cluster 1, 2, 3 and 4, while $n_{c_n}$ represents the normal operating states in case of generalized clusters.
Input  : An unexpected phenomena of three phase $(L-L-L)$ fault $(f_{c1})$ in cluster 1 with
         corresponding smaller delay, which doesn't causes wind turbines tripping $(wtt)$ in cluster 1 of SSG
Input  : A set of delay in all clusters cause by an occurrence of TPF in cluster 1 of SSG
         $(d_{e_1}, d_{e_2}, \ldots\ldots, d_{e_k})$
\\ $d_{e_1}, d_{e_2}, d_{e_3}, d_{e_4}$, corresponds to delay in cluster 1, 2, 3 and 4, while dek represents the delay in case of generalized clusters
Output: A set of the following transition states for all clusters in order to make up delays caused
        by the occurrence of TPF at cluster 1
        $(t_{c_j} \rightarrow t_{c_{j+1}})$
while $(f_1)$ do
    assign next transition state to compensate for delay due to an occurrence of three phase (L-L-L) fault
    \\ Fault $f_{c_1}$ occurred at cluster 1, which causes a delay $d_{e_1}, d_{e_2}, d_{e_3}$ and $d_{e_4}$ in corresponding 4 clusters
    if Cluster 1 $\rightarrow f_{c_1} \rightarrow d_{e_1} + d_{e_{1+0.01s}}$ then
        Next transition, $t_{c_{j+1}} \rightarrow$ Super Smart Node
    \\ Fault $f_{c_1}$ at cluster 1 causes a delay $d_{e_1}$ in clusters 1
    else if Cluster 2 $\rightarrow f_{c_1} \rightarrow d_{e_2} + d_{e_{2+0.01s}}$ then
    Next transition, $t_{c_{j+1}} \rightarrow$ Super Smart Node
    \\ Fault $f_{c_1}$ at cluster 1 causes a delay $d_{e_2}$ in clusters 2
    else if Cluster 3 $\rightarrow f_{c_1} \rightarrow d_{e_3} + d_{e_{3+0.01s}}$ then
    Next transition, $t_{c_{j+1}} \rightarrow$ Super Smart Node
    \\ Fault $f_{c_1}$ at cluster 1 causes a delay $d_{e_3}$ in clusters 3
    else if Cluster 4 $\rightarrow f_{c_1} \rightarrow d_{e_4} + d_{e_{4+0.01s}}$ then
    Next transition, $t_{c_{j+1}} \rightarrow$ Super Smart Node
    \\ Fault $f_{c_1}$ at cluster 1 causes a delay $d_{e_4}$ in clusters 4
    else if
    Cluster 1 + Cluster 2 + Cluster 3 + Cluster 4 $\rightarrow f_{c_1} \rightarrow d_{e_1} + d_{e_{1+0.01s}} \rightarrow d_{e_2} + d_{e_{2+0.01s}} \rightarrow d_{e_3} + d_{e_{3+0.01s}} \rightarrow d_{e_4} + d_{e_{4+0.01s}}$ then
    Next transition, $t_{c_{j+1}} \rightarrow$ Super Smart Node
    \\ Fault $f_{c_1}$ at cluster 1 combine effects on all clusters
    else
        next transition, $t_{c_{j+1}} \rightarrow (n_{c_1} \rightarrow n_{c_n})$
    All clusters operating in its normal states end
    Send $t_{c_{j+1}}$ transition state as an input to Algorithm 1
end
```

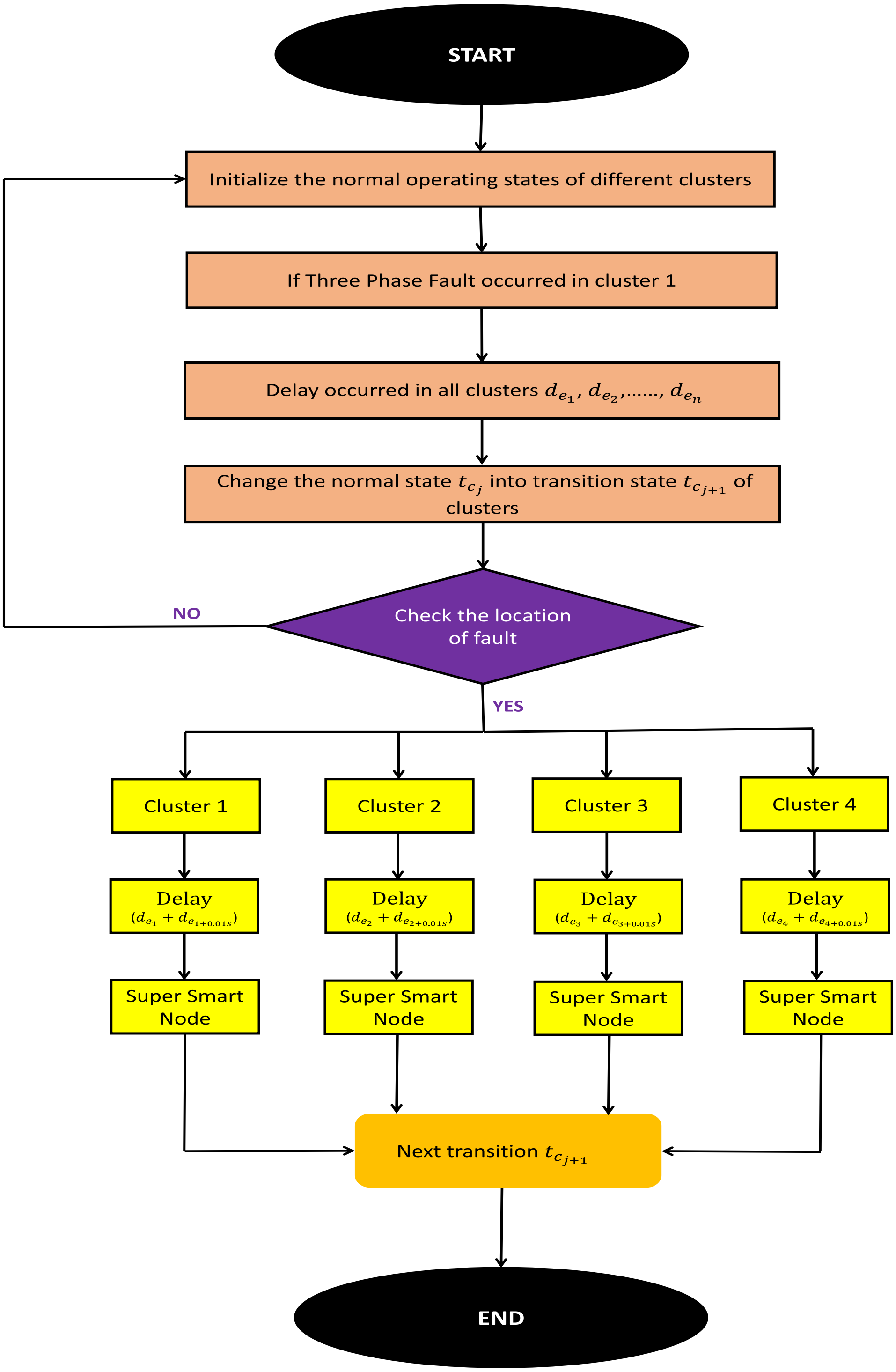


FIGURE 4. Flow chart of Algorithm 1.

larger delay in SSG. Power quality disturbances got more attention in case of an occurrence of TPF with corresponding larger delay, which causes a significant transient stability issue in SSGs. Therefore, in order to analyzed these two future contingencies issues in SSGs, we consider a scenario of $D^f(t)$ and $G^f(t)$. Additionally, to support load flow balancing across distinct RERs of four clusters in SSGs, the $G^f(t)$ must be synchronised with $D^f(t)$ in order to meet the criteria for synchronous consistency between the generation and demand response behavior, i.e.,

$$G^f(t) = D^f(t) + r_0 \tag{1}$$

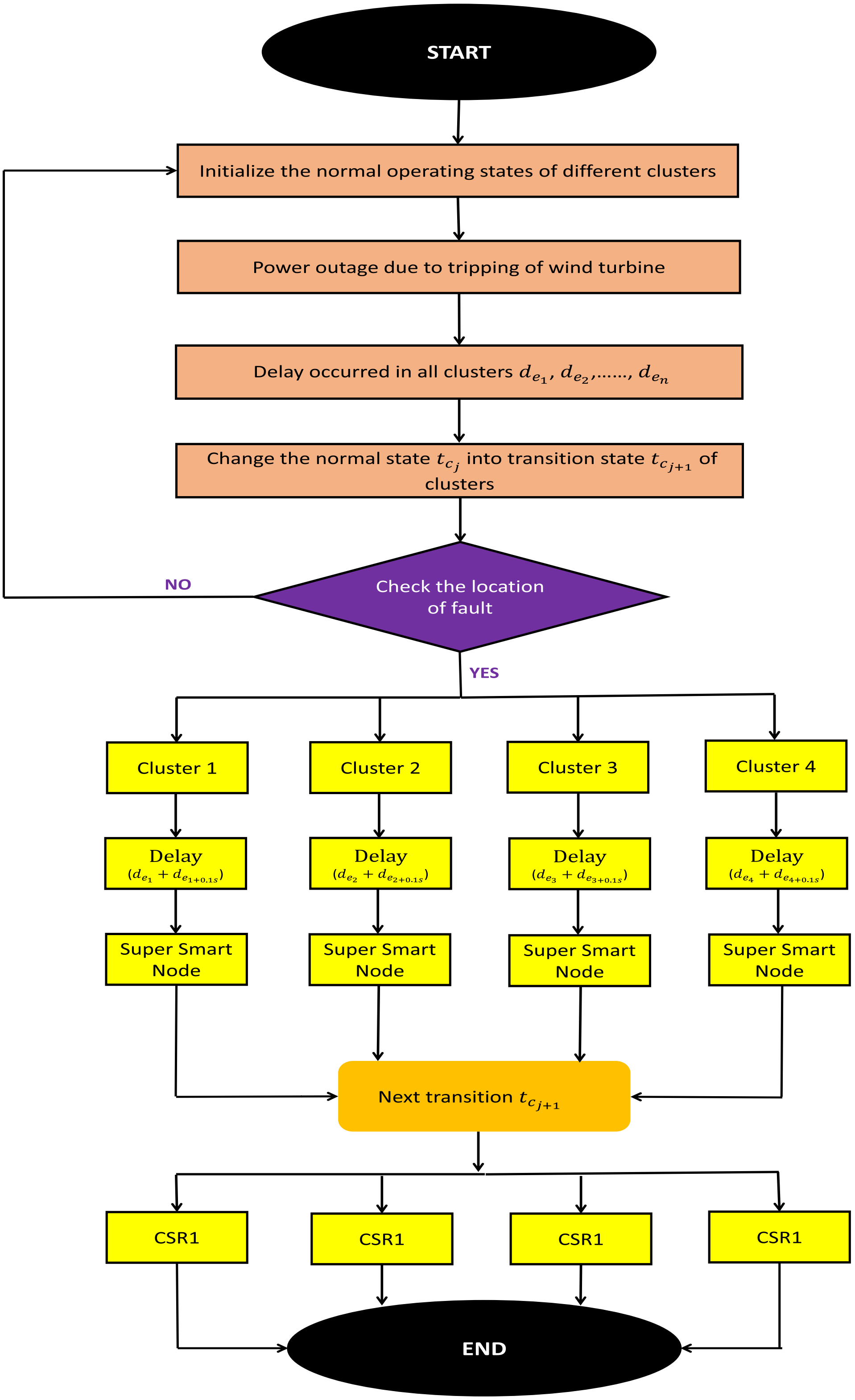


FIGURE 5. Flow chart of Algorithm 2.

where, r_0 denotes the nominal reserve, i.e., supply from the SSN transmission network, in order to achieve synchronization between $G^f(t)$ and $D^f(t)$. In this case scenario, we considered an effect of $G^f(t)$ and $D^f(t)$ response patterns by regularly providing the returning demand $B(t)$, in terms of adjusting r_0 through SSN transmission network, in order

Algorithm 2

```
Input  : A set of normal operating states of different clusters in SSG ($n_{c_1}, n_{c_2}, \ldots\ldots, n_{c_n}$),
Input  : An unexpected occurrence of three phase (L-L-L) fault ($f_{c_1}$) in cluster 1 with corresponding larger delay, which causes wind turbines tripping (wtt) in cluster 1 of SSG
Input  : A set of power outage in all clusters due to tripping of wind turbines in cluster 1 of SSG ($p_{c_1}, p_{c_2}, \ldots\ldots, p_{c_k}$)
\\ $p_{c_1}, p_{c_2}, p_{c_3}, p_{c_4}$, corresponds to power outage in cluster 1, 2, 3 and 4, while $p_{c_k}$ represents the power outage in case of generalized clusters.
Input  : A set of delay in terms of transients in all clusters due to occurrence of TPF in cluster 1 of SSG ($d_{e_1}, d_{e_2}, \ldots\ldots, d_{e_k}$)
\\ $d_{e_1}, d_{e_2}, d_{e_3}, d_{e_4}$, corresponds to delay in cluster 1, 2, 3 and 4, while dek represents the delay in case of generalized clusters
Output: A set of next transition state for all clusters in terms of compensating power outages ($t_{c_j} \rightarrow t_{c_{j+1}}$)
while $(f_1)$ do
    assign next transition state to compensate for delay due to an occurrence of three phase (L-L-L) fault
    \\ Fault $f_{c_1}$ occurred at cluster 1, which causes a delay $p_{c_1}, p_{c_2}, p_{c_3}$ and $p_{c_4}$ in corresponding 4 clusters
    if $Cluster\ 1 \rightarrow Power\ Drop = n_{c_1} - p_{c_1(wtt \rightarrow cluster1)}$ $Cluster\ 1 \rightarrow d_{e_1} = d_{e_{1+0.01s}}$ then
        Next transition, $t_{c_{j+1}} \rightarrow$ Super Smart Node $\rightarrow$ CSR 1
    \\ Fault $n_{c_1} - p_{c_1}$ and $d_{e_1} = d_{e_{1+0.01s}}$ gives power drop and transients delay in cluster 1 due to tripping of its RERs (Incorporating CSR 1 in SSN transmission network is necessary)
    else if $Cluster$ 2 $\rightarrow$Power Drop $= n_{c_2} - p_{c_2(wtt \rightarrow cluster2)}$ Cluster 2 $\rightarrow d_{e_2} = d_{e_{2+0.01s}}$ then
    Next transition, $t_{c_{j+1}} \rightarrow$ Super Smart Node $\rightarrow$ CSR 2
    \\ Fault $n_{c_2} - p_{c_2}$ and $d_{e_2} = d_{e_{2+0.01s}}$ gives power drop and transients delay in cluster 1 due to tripping of its RERs (Incorporating CSR 2 in SSN transmission network is necessary)
    else if $Cluster$ 3 $\rightarrow$Power Drop $= n_{c_3} - p_{c_3(wtt \rightarrow cluster3)}$ Cluster 3 $\rightarrow d_{e_3} = d_{e_{3+0.01s}}$ then
    Next transition, $t_{c_{j+1}} \rightarrow$ Super Smart Node $\rightarrow$ V2G
    \\ Fault $n_{c_3} - p_{c_3}$ and $d_{e_3} = d_{e_{3+0.01s}}$ gives power drop and transients stability delay issues in cluster 3 due to tripping of RERs in cluster 1 in case of an occurrence of TPF (Incorporating V2G in SSN transmission network is necessary)
    else if $Cluster$ 4 $\rightarrow$Power Drop $= n_{c_4} - p_{c_4(wtt \rightarrow cluster4)}$ Cluster 2 $\rightarrow d_{e_4} = d_{e_{4+0.01s}}$ then
    Next transition, $t_{c_{j+1}} \rightarrow$ Super Smart Node $\rightarrow$ CSR 3
    \\ Fault $n_{c_4} - p_{c_4}$ and $d_{e_4} = d_{e_{4+0.01s}}$ gives power drop and transients delay in cluster 1 due to tripping of its RERs (Incorporating CSR 3 in SSN transmission network is necessary)
    else if $Cluster$ 1 + $Cluster$ 2 + $Cluster$ 3 + $Cluster$ 4 $\rightarrow$Power Drop $= n_{c_1} - p_{c_1(wtt \rightarrow cluster1)} \rightarrow n_{c_2} - p_{c_2(wtt \rightarrow cluster2)} \rightarrow n_{c_3} - p_{c_3(wtt \rightarrow cluster\ 3)} \rightarrow n_{c_4} - p_{c_4(wtt \rightarrow cluster4)}$ and Clsuter 1, 2, 3 and 4 (Delay) $\rightarrow d_{e_1} = d_{e_1} + d_{e_{1+0.1s}} \rightarrow d_{e_2} = d_{e_2} + d_{e_{2+0.1s}} \rightarrow d_{e_3} = d_{e_3} + d_{e_{3+0.1s}} \rightarrow d_{e_4} = d_{e_4} + d_{e_{4+0.1s}}$ then
    Next transition, $t_{c_{j+1}} \rightarrow$ Super Smart Node $\rightarrow$ CSR$_1$ $\rightarrow$ CSR$_2$ $\rightarrow$ CSR$_3$ $\rightarrow$ CSR$_4$
    \\ Equalize power sharing is achieved by incorporating CSR 1, CSR 2, V2G and CSR 3 in SSN transmission network in order to accommodate power drop in each cluster. These power drops, i.e.,$n_{c_1} - p_{c_1}, n_{c_2} - p_{c_2}, n_{c_3} - p_{c_3}$ and $n_{c_4} - p_{c_4}$ in cluster 1, 2, 3 and 4 will continues the feedback loop as shown in Fig. 1 and it can be determined from frustrated demand $F(t)$, i.e., referred equation 15. Moreover, in this case scenario only V2G is considered to be a valuable resource to compensate transients delay issue of cluster 3, i.e., $d_{e_3} = d_{e_3} + d_{e_{3+0.1s}}$ Whereas, transients delay issues in cluster 1, 2 and 4, i.e., $d_{e_1} = d_{e_1} + d_{e_{1+0.1s}}$, $d_{e_2} = d_{e_2} + d_{e_{2+0.1s}}$ and $d_{e_4} = d_{e_4} + d_{e_{4+0.1s}}$ are still there.
    else
        next transition, $t_{c_{j+1}} \rightarrow (n_{c_1} \rightarrow n_{c_n})$
    end
    Send $t_{c_{j+1}}$ transition state as an input to Algorithm 1
end
```

to maintain balanced power or in other words a synchronous stability in $G^f(t)$ and $D^f(t)$.

In order to confirm the aforementioned case situation, and taking into account the previously mentioned SSG contingency problems, we presume that an SSG may be sensitive to TPF. Suppose that $\frac{1}{\lambda}$ is the average delay time slot. The average delay A caused by a TPF occurring in SSG can be calculated as follows;

$$A = \frac{1}{\lambda} \tag{2}$$

The average delay in eq. (2) caused by a TPF in SSGs equal to only one time frame. So, a more generalized version of eq. (2) may be represented as follows in eq. (3) in the existence of a closed loop probabilistic model depicted in Fig. 3:

$$A = \frac{1}{\sum_{i_{TPF}=1}^{n_1} \lambda_{i_{TPF}}} \tag{3}$$

where, $\lambda_{i_{TPF}}$ denotes the TPF delay for every single iteration, in terms of a closed loop probabilistic model is depict in Fig. 3 and n_1 represents the impact of TPF on a network which is based on synchronization of four clusters includes every one having three RERs, consisting of total twelve RERs, i.e., ($n_1 = 12$), having an interconnection in a form of SSGs power infrastructure.

Similarly, for addressing an issue of demand response pattern in a real time scenario, as in case of SSGs, a case scenario is considered, in which the actual demand $D^a(t)$ and $D^f(t)$ are synchronized with each other, by considering the effect of some irregularities in the form of randomness $R_D(t)$ in a power system, i.e.

$$D^a(t) = D^f(t) + R_D(t) \tag{4}$$

where $R_D(t)$ represents the difference or variations between the actual and forecast demand Da(t) and Df(t) respectively. It is a stochastic because the nature of renewable energy source is stochastic due to fluctuating and uncontrollable source of power [108]. It can be described by stochastic nature of uncertainty. The stochastic uncertainty problem can be solved by stochastic programming techniques proposed in [109], [110], and [111]. By incorporating the average delay model in eq. (3) due to an occurrence of TPF into eq. (4) as,

$$D^a(t) = \left\{ \left[D^f(t) \times \left(\frac{1}{\sum_{i_{TPF}=1}^{n_1} \lambda_{i_{TPF}}} \right) \right] \right\} \tag{5}$$

eq. (5) can be expressed as a generalized equation to constantly monitor SSG in the form of a closed loop control system probabilistic model as illustrated in Fig. 3.

$$D^a(t) = \sum_{i=1}^{n} \left\{ \left[D_i^f(t) \times \left(\frac{1}{\sum_{i_{TPF}=1}^{n_1} \lambda_{i_{TPF}}} \right) \right] + R_{D_i}(t) \right\} \quad (6)$$

where, $R_D(t)$ shows the randomness in $D^a(t)$ and $D^f(t)$, and can be calculated by using probabilistic model of an autocorrelation, i.e.,

$$R_D(t) = E[D^a(t)D^f(t)], \quad (7)$$

The synchronous stability obtained when, $D^a(t) \rightarrow D^f(t)$, the deviation of random $R_D(t) \rightarrow 0$,

$$G^f(t) = D^f(t) \quad (8)$$

Likewise, for exploring an issue of generation response behaviour in practical time scenario, as in case of SSGs, a case scenario is considered in which, the true supply $G^f(t)$ and early supply $G(t-1)$ are synchronized with one another and $G^f(t)$in addition to some randomness $R_G(t)$ in a power system,

$$G^a(t) = G(t-1) + G^f(t) + R_G(t) \quad (9)$$

where, $G(t-1)$ is the parameter which is used for controlling purpose, which moves back the closed loop power system network model to previous time frame in practical scenario to constant a balanced between demand and generation response pattern in order to achieved an optimum load flow balancing, as in case of SSGs power infrastructure.

Now, eq. (9) may be written as a generic equation by including the average delay model in eq. (3) caused by TPF into eq. (9) and also in perspective of a closed loop control system probabilistic model as illustrated in Fig. 3.

$$D^a(t) = \sum_{i=1}^{n} \Bigg[\Bigg(G_i(t-1) \times \Bigg(\frac{1}{\sum_{i_{TPF}=1}^{n_1} \lambda_{i_{TPF}}} \Bigg) \Bigg) + \Bigg(G_i^f(t) \times \Bigg(\frac{1}{\sum_{i_{TPF}=1}^{n_1} \lambda_{i_{TPF}}} \Bigg) \Bigg) + R_{G_i}(t) \Bigg] \quad (10)$$

where, $R_G(t)$ shows the deviation patterns between $G^a(t)$ and $G^f(t)$, and can be calculated by proposing probabilistic model of an autocorrelation, i.e.,

$$R_G(t) = E[G^a(t)G^f(t)] \quad (11)$$

Similarly, when, $G^a(t) \rightarrow G^f(t)$, the random deviation $R_G(t) \rightarrow 0$, which stabilizes the SSGs in terms of an achieving synchronous stability between $G^f(t)$ and $D^f(t)$.

Furthermore, to make sure that $R_G(t) \rightarrow 0$ i.e., the tuning of control parameter should be done for achieving synchronization between $G^f(t)$ and $D^f(t)$.

Moreover, the shortage of power due to an occurrence of TPF in SSG can be expressed in terms of frustrated demand $F(t)$ as,

$$F(t) = E^a(t) - G^a(t) \quad (12)$$

Consequently, in order to obtain the best load flow balancing between generation and demand response patterns, the phenomenon of an expressed demand $E^a(t)$ must always be satisfied at a defined delay time.

The $F(t)$ take place, when

$$E^a(t) > G^a(t) \quad (13)$$

Examining the average delay model in eq. (3) caused by TPF, eq. (12) can be rewritten as,

$$F(t) = \left[\left(E_i^a(t) - G_i^a(t) \right) \times \left(\frac{1}{\sum_{i_{TPF}=1}^{n_1} \lambda_{i_{TPF}}} \right) \right] \quad (14)$$

Substituting the generalized expression in context of closed loop probabilistic model as illustrated in Fig. 3, eq. (14) can be rewritten as,

$$F(t) = \sum_{i=1}^{n} \left[\left(\frac{(E_i^a(t) - G_i^a(t))}{n} \right) \times \left(\frac{1}{\sum_{i_{TPF}=1}^{n_1} \lambda_{i_{TPF}}} \right) \right] \quad (15)$$

where $F(t)$ acts as a feedback channel and is sent back into the power system network as $B(t)$, or returning demand, plus closed loop lag, i.e., λ_{c_1}. Hence, the term for the backlogged demand $B(t)$ is the product of $F(t)$ and closed loop corresponding delay λ_{c_1},

$$B(t) = \left(\frac{1}{\sum_{c_1=1}^{n_1} \lambda_{c_1}} \right) \times \left(E^a(t) - G^a(t) \right) \quad (16)$$

Incorporating the average delay model due to TPF in eq. (3) into eq. (16) and also expressing $B(t)$ in a form a generalized expression, eq. (16) can be expressed as

$$B(t) = \left(\frac{1}{\sum_{c_1=1}^{n_1} \lambda_{c_1}} \right) \times \sum_{i=1}^{n} \left[\left(\frac{(E_i^a(t) - G_i^a(t))}{n} \right) \times \left(\frac{1}{\sum_{i_{TPF}=1}^{n_1} \lambda_{i_{TPF}}} \right) \right] \quad (17)$$

Similarly, the reserve $r(t)$ expression can be shown as,

$$r(t) = G^a(t) - E^a(t) \quad (18)$$

The SSG should be in a reserve state, when

$$G^a(t) > E^a(t) \quad (19)$$

Now, by taking into account the average delay model in eq. (3) as well as an extended expression in the context of a closed loop probabilistic model, as illustrated in Fig. 3, eq. (18) may be recast as follows;

$$r(t) = \sum_{i=1}^{n} \left[\left(G_i^a(t) - E_i^a(t) \right) \times \left(\frac{1}{\sum_{i_{TPF}=1}^{n_1} \lambda_{i_{TPF}}} \right) \right] \tag{20}$$

The following should be the threshold policy in the context of reserve $r(t)$ criteria, if

$$r(t) < r_0 \tag{21}$$

Then we have to increase the $G^a(t)$ through SSN transmission network, in order to approach $r(t)$ to ro as closely as possible (considering the ramp down constraints), if

$$r_0 < r(t) \tag{22}$$

then, minimizes the $G^a(t)$ in order to approach $r(t)$ to ro as closely as possible (considering the ramp down constraints). where ramping limitations are given;

$$r_0 \leq G(t) - G(t-1) \leq r_0 \tag{23}$$

From eq. (9), we can easily expressed $G(t)- G(t-1)$ in terms of an expression of $G^f(t) + R_G(t)$, so now eq. (23) will becomes,

$$r_0 \leq G^f(t) + R_G(t) \leq r_0 \tag{24}$$

The primary issue that has to be solved in this scenario is maintaining constant stability of the returning or backlogged demand or $B(t)$, in every condition. By reducing $R_G(t)$ via the SSN transmission network, this may be accomplished. The ramping up and ramping down requirements from eqs. (21) and (22), we must regulate the parameter $r(t)$ in order to synchronize it with r_0 for achieving the goal. As a result, eq. (24) may be expressed as follows by minimizing $R_G(t)$;

$$r_0 \leq G^f(t) \leq r_0 \tag{25}$$

from eq. (1), $G^f(t)$ can be synchronized to $D^f(t)$, i.e., eq. (25) can be expressed as,

$$r_0 \leq D^f(t) \leq r_0 \tag{26}$$

Through eq. (26), synchronous stability or in other words in the event that TPF in SSGs occurs, load flow balancing between the demand and generation response pattern may be accomplished, by utilizing SSN transmission network using TNP proactive approach. In this research work, our main claim is that a large penetration of RERs in a form of different clusters in case of SSGs should be properly coordinated with the different receiving side power grid stations through probabilistic model of TNP, i.e., SSN. The SSN properly accommodate load flow balancing between different clusters of SSGs, even in case of an occurrence of TPF with corresponding smaller delay in SSGs. The same mathematical modeling has been formulated for V2G and CSRs, with the corresponding difference in a TPF delay time, i.e., λ_i, that depend on TPF that occurred along with corresponding larger delay, it give rise to tripping of certain RERs in SSGs. Therefore, V2G and CSRs must be incorporated in SSN transmission network to completely optimized the SSG for load flow balancing and transients stability. CSRs further optimizes SSG for load flow balancing, whereas V2G incorporation in SSN transmission network further contributes to both load flow balancing and transients stability improvement in SSGs.

If the value of $R_G(t)$ is greater this mean that the shortage of power is large in SSG due to fault that occurred with larger delay. If CSR is unable to fulfill the requirement of the power in SSGs then V2G is enable to provide power to the SSGs. Therefore, the same mathematical model for both CSR and V2G, only the difference is the availability of power, however the minimum time (delay) required for battery (V2G) than CSR to supply power to the SSG [40]. The mathematical model of spinning reserves based on electric vehicle has been developed and optimizes the scheduling cost for spinning reserve and users in V2G network [112]. The electric vehicle operates as a spinning reserve power source, it provides quick power to grid according to its requirements [113].

The following assumptions can be considered by performing probabilistic load flow analysis [114];

- The load flow equations are to be linearized;
- The power injected from different sources at node are independent;
- The network configuration is assumed to be a constant parameter;
- The discrete and Gaussian probability distribution function are assumed for the conventional generation source and load respectively.

In this work an analytical procedure has consideres for the probabilistic load flow analyses with help of uncertainty modelling as shown in Fig. (46). Convolutional methods and cumulant methods are two categories of analytical techniques. The primary idea behind the analytical technique is simply mathematical, including the convolution of known probability density distribution functions of generated and utilized power in order to get the probability density distribution functions of the associated stochastic variable system states [115]. For some predicted input variable values, load flow equations are linearized by developing them in the Taylor series [116].

A conventional convolution approach was used in the initial generation of analytically based PLF algorithms [117]. Even after using a discrete convolution, such as a discrete convolution in the frequency domain by performing Fourier Transform [118], this still involves an intensive convolution computation for PLF. Convolution methods are rarely used in contemporary studies. Gaussian mixture models and sequence operation theory were used in a few recent efforts to improve the convolution method's performance [119], [120].

The idea of the cumulants was first presented to reduce the load of computing and convolution calculation. These techniques work by substituting the distribution's cumulants for the probability distribution's instances, then conducting the computation using the cumulants. The system's input-output sensitivity ought to then be determined, often utilizing a number of deterministic load flow simulations. The output of cumulants is then computed using this level of sensitivity [121].

B. CONTINUOUS SPINNING RESERVES NON-COOPERATIVE CONTROL BASED PROBABILISTIC MODELING

As a result of TPF occurring in SSGs, it is necessary to be able to tolerate abrupt power interruptions, an integrated CSRs non cooperative control based model in SSN transmission network is operated. A CSR may be able to provide services in response to various power system emergencies, and provide benefits in terms of sustainability and economical operations of power systems, as in case of SSGs.

In the event that an SSG becomes more vulnerable to TPF with a corresponding greater delay, which causes the tripping of wind turbines nearest to fault locations. Therefore, in order to compensate these power outages due to tripping of certain RERs, switching of already incorporated CSRs in SSN transmission network must be necessary. These CSRs optimizes efficiently the load flow balancing of all clusters in SSGs, but the power quality issues due to an occurrence of TPF in SSGs is still there, which causes a significance delay in the operations of different CSRs. The average delay A in case of an operation of CSRs can be written as, i.e., eq. (2) will become,

$$A = \frac{1}{\lambda_{i_1} + \lambda_{i_2} + \lambda_{i_3}} \tag{27}$$

The delay incurred due to an operation of CSRs in SSGs in eq. (27) is upto three time slots, as CSR 1, CSR 2 and CSR 3 are operated separately at cluster 1, 2 and 4 of SSGs. Now, by considering eq. (27) in terms of CSRs delay λ_{CSRs} i.e.,

$$\lambda_{i_{CSRs}} = \lambda_{i_1} + \lambda_{i_2} + \lambda_{i_3} \tag{28}$$

then, eq. (27) will become,

$$A = \frac{1}{\lambda_{i_{CSRs}}} \tag{29}$$

The above average delay model is only applicable for three clusters, as we have three CSRs that are correspondingly operates between these clusters. In order to generalize above model to make it applicable for any number of clusters, the eq. (29) can be rewritten as;

$$A = \sum_{i_{CSRs}=1}^{n} \left[\frac{1}{\lambda_{i_{CSRs}}} \right] \tag{30}$$

A probabilistic model has been designed to handle the issue of power outages, in terms of an occurrence of TPF with associated higher delay in SSGs, in order to estimate the demand of $r(t)$ and it can be expressed as, i.e., eq. (20) will become,

$$r(t) = \sum_{i=1}^{n} \left[\left(G_i^a(t) - E_i^a(t) \right) \times \sum_{i_{CSRs}=1}^{n} \left(\frac{1}{\lambda_{i_{CSRs}}} \right) \right] \tag{31}$$

Similarly, $D^a(t)$ and $G^a(t)$ in eqs. (6) and (10) will now becomes,

$$D^a(t) = \sum_{i=1}^{n} \left[\left(D_i^f(t) \right) \times \sum_{i_{CSRs}=1}^{n} \left(\frac{1}{\lambda_{i_{CSRs}}} \right) + R_{D_i}(t) \right] \tag{32}$$

$$\begin{aligned} G^a(t) = \sum_{i=1}^{n} \Bigg[& \left(G_i(t-1) \times \sum_{i_{CSRs}=1}^{n} \left(\frac{1}{\lambda_{i_{CSRs}}} \right) \right) \\ & + \left(G_i^f(t) \times \sum_{i_{CSRs}=1}^{n} \left(\frac{1}{\lambda_{i_{CSRs}}} \right) + R_{G_i}(t) \right) \Bigg] \end{aligned} \tag{33}$$

where, $F(t)$, $B(t)$ in eqs. (15) and (17) will now becomes,

$$F(t) = \sum_{i=1}^{n} \left[\left(E_i^a(t) - G_i^a(t) \right) \times \sum_{i_{CSRs}=1}^{n} \left(\frac{1}{\lambda_{i_{CSRs}}} \right) \right] \tag{34}$$

$$\begin{aligned} B(t) = \sum_{i_{CSRs}=1}^{n} \left[\frac{1}{\lambda_{i_{CSRs}}} \right] \times \sum_{i=1}^{n} \Bigg[& \left(E_i^a(t) - G_i^a(t) \right) \\ & \times \sum_{i_{CSRs}=1}^{n} \left(\frac{1}{\lambda_{i_{CSRs}}} \right) \Bigg] \end{aligned} \tag{35}$$

C. COOPERATIVE CONTROL BASED V2G PROBABILISTIC MODELING

In order to address the problem of irregularity in the form of randomness that exist in the power system such as TPF occurred along with corresponding larger delay, a cooperative control probabilistic model based on V2G incorporation in SSN transmission network of SSGs is also designed. In the event that TPF occurs in SSGs, a V2G has the capacity to regulate the power system owing to the resulting power quality disturbances, stabilizing the entire power systems in a short amount of time. Moreover, V2G not only optimizes SSGs for load flow balancing, but also should be consider as a valuable resource for minimizing transients stability issues in SSGs.

In order to verify the potential of V2G in SSGs, we suppose that SSG is now potentially vulnerable to TPF where vulnerability is the inability of the system to withstand an unwanted event. The purpose of a vulnerability assessment is to identify a power system capacity to continue providing service when an unexpected severe situation event happened [122], which mean that SSG must be able to maintain its stability in term of high-quality power flow based on proposed algorithm in case of occurrence of Three Phase Fault (TPF). The average delay A in case of an operation of V2G in SSGs, i.e, eq. (29) will now become,

$$A = \frac{1}{\lambda_{V2G}} \tag{36}$$

The above average delay model is only applicable for one cluster, as V2G is only operated at cluster 3 of SSGs, i.e., V2G average delay corresponds to only one time slot. The minimum time required for V2G to supply power to the SSG in case of TPF, because it contains only battery that directly supply power without any external source. By considering the general case that TPF may be occurred in any cluster then battery will supply power with minimum time interval if CSR failed due to availability of insufficient power then.,

$$\lambda_{V2G} \ll \lambda_{CSRs} \tag{37}$$

whereas, in term of generalized expression in a form of closed loop probabilistic model as depicted in Fig. 3, eq. (36) can be rewritten as,

$$A = \sum_{i_{V2G}=1}^{n} \left[\frac{1}{\lambda_{V2G}} \right] \tag{38}$$

Likewise, for V2G the reserve $r(t)$ is, i.e., eq. (31) will become,

$$r(t) = \sum_{i=1}^{n} \left[\left(G_i^a(t) - E_i^a(t) \right) \times \sum_{i_{V2G}=1}^{n} \left(\frac{1}{\lambda_{i_{V2G}}} \right) \right] \tag{39}$$

For V2G the $D^a(t)$ and $G^a(t)$ can be followed as, i.e., eqs. (32) and (33) will now become,

$$D^a(t) = \sum_{i=1}^{n} \left[\left(D_i^f(t) \right) \times \sum_{i_{V2G}=1}^{n} \left(\frac{1}{\lambda_{i_{V2G}}} \right) + R_{D_i}(t) \right] \tag{40}$$

$$\begin{aligned} G^a(t) = \sum_{i=1}^{n} \Bigg[\Bigg(G_i(t-1) \times \sum_{i_{V2G}=1}^{n} \left(\frac{1}{\lambda_{i_{V2G}}} \right) \Bigg) \\ + \left(G_i^f(t) \times \sum_{i_{V2G}=1}^{n} \left(\frac{1}{\lambda_{i_{V2G}}} \right) + R_{G_i}(t) \right) \Bigg] \end{aligned} \tag{41}$$

Likewise, $F(t)$ and $B(t)$ in eqs. (34) and (35) will now becomes,

$$F(t) = \sum_{i=1}^{n} \left[\left(E_i^a(t) - G_i^a(t) \right) \times \sum_{i_{V2G}=1}^{n} \left(\frac{1}{\lambda_{i_{V2G}}} \right) \right] \tag{42}$$

$$\begin{aligned} B(t) = \sum_{i_{V2G}=1}^{n} \left[\frac{1}{\lambda_{i_{V2G}}} \right] \times \sum_{i=1}^{n} \Bigg[\left(E_i^a(t) - G_i^a(t) \right) \\ \times \sum_{i_{V2G}=1}^{n} \left(\frac{1}{\lambda_{i_{V2G}}} \right) \Bigg] \end{aligned} \tag{43}$$

Moreover, in this case V2G technology may serve as a power buffer to handle the RERs' volatility, improving the RERs capacity to withstand power transients in the event of TPF in SSGs. Let's consider a scenario of forecasted demand like switching peak to be $D_{t_1}^f$ and the forecasted RERs to cope up with this forecasted demand due to TPF in SSGs are $V_{t_1}^f$. Currently, it is quite challenging to deal with transitory impacts with RERs owing to TPF in SSGs because of the reduced power dispatchability of RERs. Therefore, the power dispatchability improvement and transients stability of RERs, we consider the concept of V2G in SSGs. Our control problem is to find out dispatched power schedule $P_t^f(t+f)$ for power system in order to enhance transients stability and decreases power dispatchability of RERs via V2G. This can be settled by tuning $P_t^f(t+f)$ to $(D_t^f(t+f) - V_t^f(t+f) + r_0)$, where r_0 is constant value utilizing the ramp up and ramp down constraints of eqs. (21) and (22). Hence, the final equation for $P_t^f(t+f)$ can be followed as,

$$\sum_{i=1}^{n} \left[P_{t_i}^{f_i}(t_i + f_i) \right] = \sum_{i=1}^{n} \left[\left(D_{t_i}^{f_i}(t_i + f_i) - V_{t_i}^{f_i}(t_i + f_i) \right) \right] \tag{44}$$

where, $V_{t_1}^f(t+f)$ stands for the supply from the V2G to control power outages and transient stability problems.

The aforementioned probabilistic models of the SSN transmission network using TNP, non cooperative control based CSRs and cooperative control based V2G are used for the purpose of studying reliability indices for delay in the event of TPF in SSGs. On the receiving side of various power grid stations in SSGs, necessary corrective measures, such as load flow balancing and transients stability, may be simply done by considering the aforementioned scenario.

III. SIMULATION RESULTS

We have carried out a simulation using MATLAB/Simulink in order to validate our proposed model of load flow balancing and transients stability in order to analyze the importance of a SSN for load flow balancing in SSGs, a 148 bus system model has been simulated as illustrated in Fig. 14. A simulated model has been split into four clusters, and each cluster contains three RERs that are linked to the other clusters. Moreover, cluster to cluster interconnections can be done in a form of SSN transmission network as shown in Figs. 11 and 12.

Now form a literature point of view, as we already mentioned in Section I, i.e., comparison between proposed work and methodologies of [47], [48], [49], [50], [51], and [52] in the literature have been performed for load flow balancing and [104] for transients stability analysis, as in case of smart grids power infrastructure, this article is based on a general system model in which different smart grid clusters are combine with one another in order to develop a SSGs infrastructure. Moreover, the impact of TPF on load flow balancing and transients stability in SSGs instead of smart grids is considered to be a problem formulation. Therefore, the problem formulated in this paper is new and it is significantly deviated from all earlier proposed studies. it's concluded, the proposed algorithm presented in this paper cannot be directly compared with the previous proposed algorithms in [47], [48], [49], [50], [51], [52], and [104], which is purely based on smart grid approaches for load flow balancing and transients stability analysis. In this review article we proposed two different algorithms, to cater the mentioned problem, one incorporated smart grid based approach for load flow balancing as proposed in [49] in our proposed work of SSGs to clearly illustrates the difference and significance of our analytical approach of SSN transmission network using TNP with the proposed approach in [49] for load flow balancing in SSGs. Secondly, incorporated smart grid distributed controller based approach as proposed in [104] in our proposed scenario of SSGs for transients stability analysis to clearly illustrate the difference and significance of our distributed cooperative control based V2G approach with the proposed approach in [104] in terms of enhancing transients stability issues in SSGs. Moreover, our proposed approach of SSN transmission network and V2G cooperative control based technique is suitable to both smart and SSGs power infrastructure as compared to previous proposed approaches for load flow balancing and transients stability analysis [49], [104], which is only limited to smart grids power infrastructure, as we already discussed in literature review. Moreover, it also elaborates, that why these approaches as discussed in [47], [48], [49], [50], [51], and [52] for load flow balancing and for transients stability analysis [104] is not suitable to be utilized in SSGs. Now, before discussing these algorithms in details, we must first clarify the phenomena, that why SSN is a good way to represents an electrical transmission network in order to provide an optimum load flow balancing in SSGs. This is accomplished by comparing our suggested study with the prior proposed research in [49].

To validate that suggested approach in [47], [48], [49], [50], [51], and [52] are considered to be more computationally costly and the optimum solution in a form of load flow balancing is not guaranteed to achieved, if we consider a larger deviations between loads on the receiving side (KW) of different power grid stations (MW), which is a main reason from transforming smart grids infrastructure into SSGs, a power system proposed in [49] is examined. The main intention of the proposed work in [49] is to reduce an overall cost of an energy import from the public grid, i.e.,

$$\int_0^T P_i(t)C(t)dt \rightarrow minimize, \tag{45}$$

where, the active power is represented by $P_i(t)$, which is transferred to the grid from the bus. it is considered to be positive and negative for generator and load respectively. Where $C(t)$ represents the price signal ($\$/MW$) and it is basically depend on time. The formulated problem in [49] is to find out an optimum energy/storage function $E(t)$, that will minimizes the primary objective function in eq. (45). Considering eq. (45), the cost function $V(.)$ can be represented as,

$$V(t,E) = \int_0^T P_i(t)C(t)dt \rightarrow minimize, \tag{46}$$

The main objective function as represented by eq. (45) is equal to the minimizing $V(0, 0)$ in eq. (46), i.e., minimizing an overall cost of the power system over an entire period, which initially starts from an empty storage E = 0. In this case scenario, the optimum solution is determine recursively through utilizing Bellman equation, i.e.,

$$V(t,E) = \min_{\mathrm{E(t+dt)}} \Big(\Delta V(E, E(t+dt)) + V(t+dt, E(t+dt))\Big) \tag{47}$$

The cost function $V(t,E)$ is to numerically find out by utilizing the backward recursion process. It starts from the final time, i.e., t=T, and the representation of cost function is $V(T,E) = 0$. Now, using eq. (47), the cost function can be minimized at $T - dt$, by determining $V(T - dt, E)$ for all values of the energy. This operation will continue up till the condition of i.e., $t = 0$ is reached. Fig. 6 depicts a backward recursion procedure for a one storage device.

Likewise, same procedure will be followed, if we considered another storage device in power system network. The sole difference is that the power system network now includes a new storage device, a new dimension to an existing solution space will also become added. Therefore, in case of utilizing two storage devices in an electrical network, the $(1-D)$ space problem for a single storage device is now considered to be a two dimensional $(2-D)$ space problem, having two variables, i.e., $E_i(t)$ and $E_j(t)$, both of these variable are considered to be free. The primary difference is that the cost function $V(.)$ is multidimensional now, i.e.,

$$V(t, E_i, E_j) = \int_0^T P_i(t)C(t)dt \rightarrow minimize, \tag{48}$$

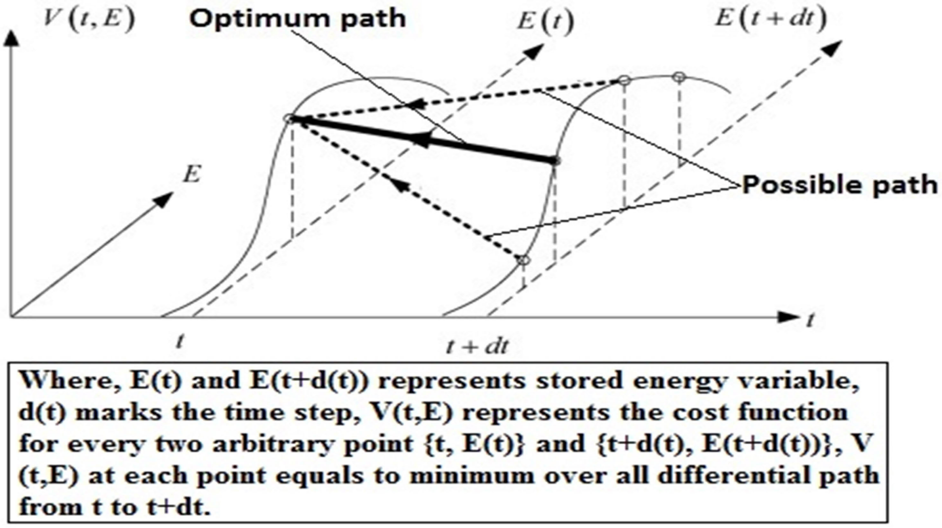
where, $E_i(t) = E_i$ and $E_j(t) = E_j$ are initial conditions. Therefore, eq. (47) will become,

$$\begin{aligned} V(t, E_i, E_j) = \min_{\mathrm{E}_i(t+dt),\mathrm{E}_j(t+dt)} \Big[& \Delta V \Big(E_i, E_i(t+dt), \\ & E_j, E_j(t+dt)\Big) + \Big(V(t+dt, E_i(t+dt), \\ & E_j(t+dt))\Big)\Big] \end{aligned} \tag{49}$$

The hybrid optimization technique has been proposed to solve out these problems more quickly. The hybrid optimization is based on AI technique to control and manage flow of energy in hybrid storage energy system [123]. The fast adaptive algorithm for optimization has been developed to solve theses problem more quickly and provide best solution of the problem. The rate of convergence for finding optimal solution has greater than other techniques proposed in [124].

A storage network having 2-D a backward recursion process is illustrated in Fig. 7.

The major limitations involved with the proposed methodology in [49] is that a proportional rise in the amount of storage devices, the power system network's computational difficulty also rises. This phenomenon is shown in Fig. 7, where the inclusion of a second storage device into a power system network also results in the addition of an additional dimension to the optimal solution. This clearly verified the limitation of the proposed work in [49] that an electrical network is only processed in seconds, if it contains only a single storage device, even if considering a large number of



Where, E(t) and E(t+d(t)) represents stored energy variable, d(t) marks the time step, V(t,E) represents the cost function for every two arbitrary point {t, E(t)} and {t+d(t), E(t+d(t))}, V (t,E) at each point equals to minimum over all differential path from t to t+dt.

FIGURE 6. Process of Backward recursion for one storage in power system network [49].

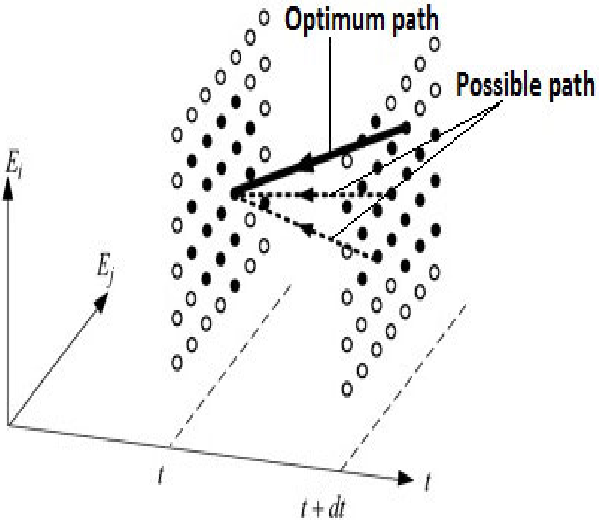


FIGURE 7. Process of Backward recursion for double storage devices in a power system network [49].

interconnections between different buses. However, an electrical network with the addition of four or five storage devices may be determined, if it includes only few number of buses. This verified the phenomena that the proposed algorithm as presented in [49] does not give the power system operators an optimum solution in terms of load flow balancing, the capacity of power system can be increases by emerging various RERs along with energy storage devices. The capacity can be increases further by increasing number of buses. Alternatively, the presented approach in [49] is only valid for limited smaller loads (KW) and not heavier loads (MW) on the receiving side of different power grid stations, which is a main reason behind transforming a smart grid power infrastructure into SSGs power infrastructure.

Moreover, we proposed an entirely different and completely new method for the usage of sophisticated storage devices, that results in a different and ideal solution that is capable of solving the mathematical complexity of power systems. Instead of focusing on the issue outlined in [49], as a function to minimized cost within constraints of utilizing few number of RERs and storage devices to adjust light loads (KW) as in case of smart grids, we integrate large number of RERs, CSRs and storage device (V2G) in a form of SSN transmission network using TNP proactive approach and utilized it as a resource to be assigned to different clusters and their corresponding power grid stations, as in case of SSGs. Instead of considering it as a cost minimization problem for suggested work in this article, we assign it as an allocation problem, where an optimum power is devoted to put up heavy loads (MW) in order to optimize the power import from different RERs, so in order to supply an minimum load flow sharing between various power grid stations of different clusters, as in case of SSGs power infrastructure.

The SSN transmission network scale free topological representation is shown in Fig. 11. This type of network representation is very useful, when calculating a risks related to random errors, since randomly disturbance at any node of a network, may relate to the high probability of low degree of connectivity in power system network. In probabilistic terms, we can classified it as, that those nodes in power system network, which are having less interconnections with one another to disturb. Due to such strong interconnectivity among different nodes in a form of SSN transmission network as in case of SSGs, we supply an autonomous flow of power control in a form of an equalize power sharing between every node and their corresponding power grid station, without taking into account specific transmission nodes links. In this scenario, proper assessment of the proposed problem has been formulated using TNP proactive approach in a form of

SSN transmission network by considering the uncertainties due to RERs and power quality disturbances caused by TPF that happened in SSGs, which accounts for both, i.e., load flow balancing and transients stability. From the point of view of regulators and policy makers, an optimal assessment in a form of a TNP, especially in case of SSGs power infrastructure is of great interest because the lack of proper coordination between the different clusters of SSGs can jeopardize the load flow sharing scenario between these clusters and therefore causes a significant power outage issues at different power grid stations of various clusters. Moreover, Fig. 11 shows the TNP in a form of SSN transmission network of just four clusters with every one including three RERs in order to give an prime, i.e., equalize load flow sharing among multi clusters and their corresponding power grid stations of SSGs. Furthermore, this TNP can be further extended for any number of generalized clusters in order to develop a more strengthen interconnected networks for SSGs power infrastructure.

Fig. 12 shows a stronger interconnectivity between various transmission substations/buses in a form of a SSN transmission network in order to provide an optimized load flow balancing in SSGs. Now, in order to consider high penetration RERs integration with one another for gaining an minimum load flow balancing in SSGs, these interconnection between different transmission substations/buses and generation planning face many problems as proposed in [125]. The flexibility of power systems during power quality disturbances, or its ability to meet the variations in load demands through using RERs in SSGs, is one such critical issue, which are receiving much attention from the researchers side. So, by taking into account the RER dependability issues that might be effectively realized in real time scenario, if we consider a case scenario of an unknown time varying additive disturbance in power system, having taken place as a result of TPF in SSGs, a more accurate evaluation of the flexibility of a power system for load flow balancing may be done. In order to achieve the best load flow balancing in SSGs, it is considered that linkage between various transmission substations/buses in the form of an SSN transmission network is a significant resource, considering the risk imposed onto the power system network by using a renewable generating resources due to its unreliable operations, especially when TPF occurred in SSGs.

Moreover, addressing an issue of variability in the RERs for load flow balancing and transients stability in SSGs, an additional level of quick response spinning reserves will also require in the SSN transmission network. For this purpose, a noncooperative control based CSRs and a cooperative control based strategies in a form of V2G is added to an SSN transmission network in order to circumvent critical situations, considering an uncertainties issues in SSGs, i.e., further optimized the power systems for load flow balancing and transients stability enhancement as depicted in Fig. 12. In the presence of power quality issues, these circumstances worsen, i.e., occurrence of TPF in SSGs, where the interaction between different RERs in a form SSN for optimum load flow balancing, the amount of RERs curtailment, which causes a significant power quality issues in SSGs and proper optimization control algorithms using CSRs and V2G in order to compensate these issues became even more complex.

A. TPF IN SSGs WITH CORRESPONDING SMALLER DELAY

The Fig. 8 analyzed the fact that due to well established interconnection in a form of SSN transmission network, a load flow balancing in terms of an equalized power sharing is obtained on each power grid station of the receiving side, i.e., Buses $B4$, $B8$ and $B12$ of cluster 1, $B28$, $B32$ and $B36$ of cluster 2, $B88$, $B92$ and $B96$ of cluster 3 and $B64$, $B68$ and $B72$ of cluster 4, even in case of an occurrence of TPF at ($t = 1s$ to $t = 1.01s$), due to reliability issues involve with the RERs, whereas reliability is the capacity of a system to operate as planned under defined conditions for a certain period of time, without any failure, and within the set of operating boundaries [126]. The capacity of the power system to meet demand at all times, which depends on the presence of enough generation and transmission infrastructure and the necessary amount of reserve, may be used to assess long-term performance. This capacity is known as adequate of power systems [127]. Due to the intermittent and irregular characteristics of renewable energy sources, the penetration of renewable energy has a considerable negative influence on reliability of the grid [128]. Therefore, the renewable energy coming from the wind or solar make the power grid is less reliable because we cannot control the wind or light coming from the sun, due to which make the power drop and it's difficult to maintain a reliability balance between demand and supply. Since the TPF interval time is very small, therefore it doesn't cause the tripping of wind turbines nearest to the fault location.

However the stability of the power system has been affected due to TPF, but its again restored due to the SSN network transmission. From Table 1, ($B4, B8, B12, B28, B32, B36, B88, B92, B96, B64, B68$) and ($B72$) represent active power buses when TPF occurred with corresponding smaller delay i.e. no tripping of wind turbine due to SSN model. The model of the wind turbine without tripping has been derived in [125], when fault occurred in power system.

In this case our demand response problem is to keep the $(D_1^f(t),\ D_2^f(t),\ D_3^f(t), \ldots\ldots D_{12}^f(t) = D_1^a(t),\ D_2^a(t),\ D_3^a(t), \ldots\ldots D_{12}^a(t))$ of the 12 receiving stations (RS), i.e., ($RS1$, $RS\ 2 \ldots\ldots\ldots RS12$) to be synchronized with one another in terms of an equalized power sharing between these receiving side power grid stations. This can be done through an SSN transmission network in SSGs, which makes $(G_1^f(t),\ G_2^f(t),\ G_3^f(t), \ldots\ldots G_{12}^f(t) = G_1^a(t),\ G_2^a(t),\ G_3^a(t), \ldots\ldots G_{12}^a(t))$ in order to achieve synchronous stability between $(G_1^f(t),\ G_2^f(t),\ G_3^f(t), \ldots\ldots G_{12}^f(t)$ and $(D_1^f(t),\ D_2^f(t),\ D_3^f(t), \ldots\ldots D_{12}^f(t)$ for different receiving side power grid stations, i.e., ($RS1$, $RS\ 2 \ldots\ldots\ldots RS12$) of SSGs. The scale free topological model of an SSN transmission network as

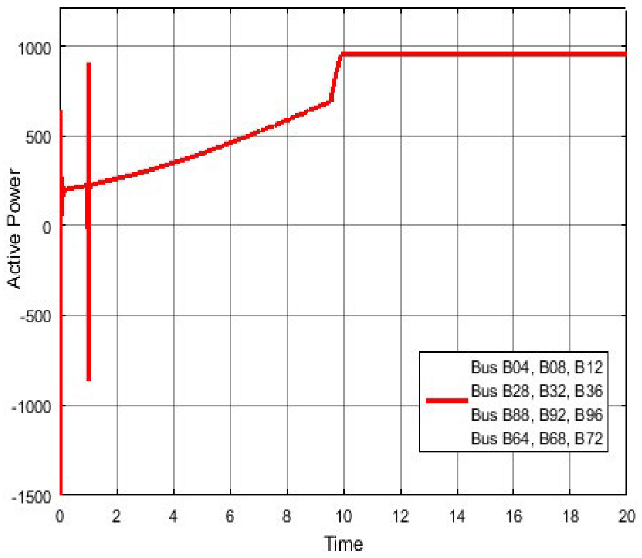


FIGURE 8. **Super smart node analysis of four clusters.**

shown in Fig. 11 is utilized in order to provide load flow balancing in terms of an equalized power sharing between 12 power grid (PG) stations $PG1$, $PG2$, $PG3\ldots..PG12$ as shown in Fig. 13.

A scale-free topology is a network whose degree of distribution follows a power law in the node, small number of nodes have large degree while greater number of nodes have small value of degree. The power law can be expressed as;

$$P(k) = \alpha K^{-}\gamma$$

where the value of α and γ are the specified network parameters [129]. The node is intersecting point of the element in the network [130]. A free scale topology has also developed for the wireless network in which the location of node should be satisfied, but new node from time to time must be introduced in wireless mesh of smart grid [131]. The model of free scale topology for wireless mesh in smart grid have been developed in [132].

B. TPF IN SSGs WITH CORREPONDING LARGER DELAY

Now let's consider the TPF occurrence time interval is upto 0.1s, i.e., ($t = 1s$ to $t = 1.1s$) as shown in Fig. 9, i.e., transients effects on different buses, which cause the tripping of the first generation resource of cluster 1 at $t = 1s$ as shown in Fig. 10, i.e., Bus $B1$ active power and Fig. 14. Due to tripping of RERs 1, it's $G^a_1(t) = 0MW$ whereas actual supply of other 11 RERs are, $G^a_2(t) = 973.6MW$, $G^a_3(t) = 973.6MW, \ldots\ldots G^a_{12}(t) = 973.6MW$. Now in order to accommodate $D^f_1(t)$, i.e., adjusting the the load requirements of tripping bus B1 of RERs 1, whose actual supply is $G^a_1(t) = 0MW$. We have to shift the active power from the other eleven RERs of $PG1$, $PG2$, $PG3\ldots.PG12$ as shown in Fig 10 and Fig 11 in order to increased $G^f_1(t)$, in other words accommodating $G^a_1(t)$ of RERs 1. Considering above scenario, the SSN transmission network as shown in Fig. 11 equalize the whole power system of four clusters having 12 RERs as shown in Fig. 14, but with up to some extent. The receiving station 2 and 3 of cluster 1, 5 and 6 of cluster 2, 8 and 9 of cluster 3 and 11 and 12 of cluster 4 active power is balanced, i.e., 850.6 MW at Buses $B8$ and $B12$ of cluster 1, 892.3 MW at Buses $B32$ and $B36$ of cluster 2, 905.7 MW at Buses $B92$ and $B96$ of cluster 3 and 892.3 MW at Buses $B68$ and $B72$ of cluster 4, also referred Table 1, considering these buses with corresponding tripping of wind turbines in SSGs due to an occurrence of TPF, i.e., SSN Tripping of WT. Whereas receiving station 1, 4, 7 and 10 of cluster 1, 2, 3 and 4 active power drops to 771.2 MW, 858.6 MW, 897.2 MW and 858.6 MW as shown in Fig 7, also referred Table 1, Buses ($B4$, $B28$, $B88$ and $B64$) active power with an occurrence of TPF with corresponding larger delay, i.e., SSN-Tripping of WT. Due to this reason, an unequal power sharing is occurred between different power grid stations, i.e., ($PG1$ with $PG2$ and $PG3$) (771.2 MW, 850.6 MW, 850.6 MW) of cluster 1, ($PG4$ with $PG5$ and $PG6$) (858.6 MW, 892.3 MW, 892.3 MW) of cluster 2, ($PG7$ with $PG8$ and $PG9$) (897.2 MW, 905.7 MW, 905.7 MW) of cluster 3, ($PG10$ with $PG11$ and $PG12$) (858.6 MW, 892.3 MW, 892.3 MW) of cluster 4. Therefore, in order to compensate these issues, an incorporation of CSR 1, 2, 3 and V2G at cluster 1, 2, 4 and cluster 3 in SSN transmission network of SSGs is necessary in order to provide an equalized power sharing between ($PG1$, PG 2, PG 3) of cluster 1, ($PG4$, PG 5, PG 6) of cluster 2, ($PG7$, PG 8, PG 9) of cluster 3, and ($PG10$, PG 11, PG 12) of cluster 4. The CSRs and V2G in SSGs will actually minimizing the randomness $R_G(t)$ in all clusters by providing an equalized power sharing between different clusters and their corresponding power grid stations. Before operating CSRs and V2G in SSN transmission network, the $R_G(t)$ in 12 power grid stations of corresponding 4 clusters of SSGs can be expressed as,

$$\begin{aligned} R_{G_1}(t)(P_{G_1}(t)) &\neq R_{G_2}(t) \\ (P_{G_2}(t)) &= R_{G_3}(t)(P_{G_3}(t)) \end{aligned} \tag{50}$$

$$\begin{aligned} R_{G_4}(t)(P_{G_1}(t)) &\neq R_{G_5}(t) \\ (P_{G_2}(t)) &= R_{G_6}(t)(P_{G_3}(t)) \end{aligned} \tag{51}$$

$$\begin{aligned} R_{G_7}(t)(P_{G_1}(t)) &\neq R_{G_8}(t) \\ (P_{G_2}(t)) &= R_{G_9}(t)(P_{G_3}(t)) \end{aligned} \tag{52}$$

$$\begin{aligned} R_{G_{10}}(t)(P_{G_1}(t)) &\neq R_{G_{11}}(t) \\ (P_{G_2}(t)) &= R_{G_{12}}(t)(P_{G_3}(t)) \end{aligned} \tag{53}$$

where $R_G(t)$ represent the difference or variation between the actual and forecast supply $G^a(t)$ and $G^f(t)$ respectively. If the variation between Ga(t) and Gf(t) is greater, then the value of $R_G(t)$ is greater, similarly if the value of $R_G(t)$ is low, it will represent the low variation between them [7]. Due to an occurrence of TPF in SSG, which causes a tripping of RERs 1 of cluster 1, it cause a random variations $R_G(t)$ between different power grid stations of their corresponding clusters due to an unequal power distributions between them. In this case

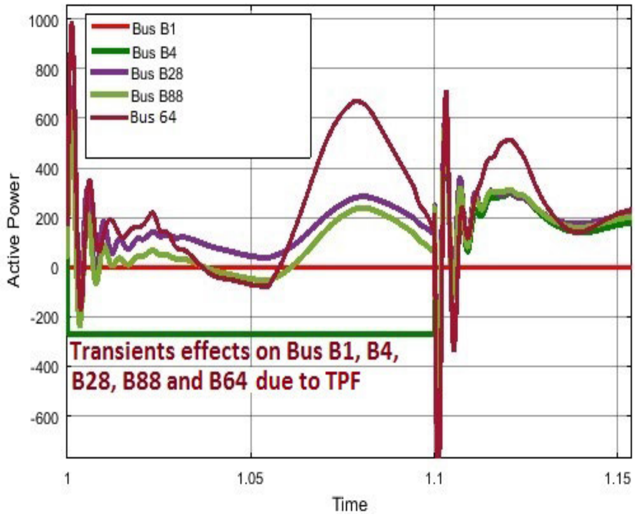


FIGURE 9. Bus B1, B4, B28, B88 and B64 active power graphs.

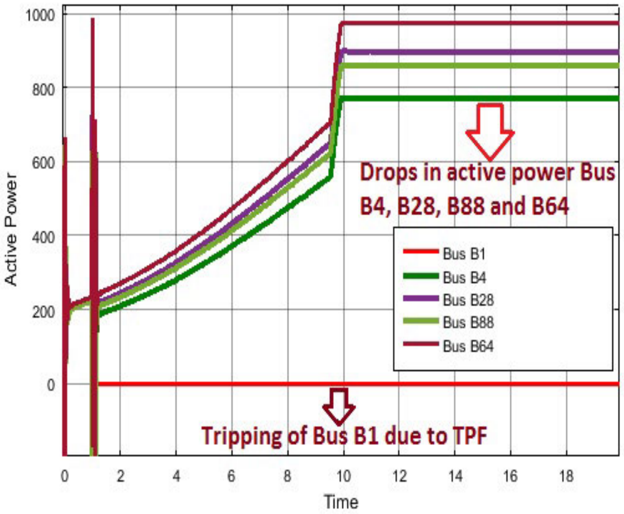


FIGURE 10. Bus B1, B4, B28, B88 and B64 active power drops graphs.

scenario, our main objective is to maintain a same amount of $R_G(t)$ for different power grid stations of each clusters, so in order to provide an equalized power sharing between these power grid stations and their corresponding clusters. Eqs. 50, 51, 52 and 53 shows the randomness between $R_{G_1}(t)$ with $R_{G_2}(t)$ and $R_{G_3}(t)$, $R_{G_4}(t)$ with $R_{G_5}(t)$ and $R_{G_6}(t)$, $R_{G_7}(t)$ with $R_{G_8}(t)$ and $R_{G_9}(t)$, and $R_{G_{10}}(t)$ with $R_{G_{11}}(t)$ and $R_{G_{12}}(t)$ which occurs due to an unequal power distribution of ($PG1$ with $PG2$ and $PG3$) of cluster 1, ($PG4$ with $PG5$ and $PG6$) of cluster 2, ($PG7$ with $PG8$ and $PG9$) of cluster 3, ($PG10$ with $PG11$ and $PG12$) of cluster 4.

The spinning reserves in a form of CSRs and V2G also provides a synchronous stability to each cluster and their corresponding power grid stations in terms of load flow balancing and transient stability in SSGs. CSRs optimizes SSGs for load flow balancing, whereas V2G is acting as a valuable resource both for load flow balancing and transients stability. In order to compensate for larger power outages, integrated CSR 1, 2 and 3 in SSN transmission network are operated in cluster 1, 2 and 4 of SSGs. These CSRs not only contributes to their corresponding clusters for load flow balancing, but they will be consider as a valuable resource for load flow sharing between different clusters as shown in Figs. 15, 16 and 17. CSR 1, 2 and 3 provides an active power of 140.9 MW, 61.8 MW and 62.1 MW, which will be distributed among different clusters as shown in Figs. 15, 16 and 17 in order to achieve a synchronous stability in terms of an equalized power sharing between different clusters and their corresponding power grid stations. The complete picture of load flow sharing between different clusters and their corresponding power grid stations through utilizing CSRs in SSN transmission network of SSGs is shown in Fig. 13. Moreover, Fig. 19 represents a better utilization of CSRs, as proved from buses $B145$ (CSR 1), $B146$ (CSR 2) and $B148$ (CSR 3), in terms of compensating large power outages of cluster 1, 2 and 4 and also shows, that inspite of achieving an equalized load flow sharing between different clusters and their corresponding power grid stations by utilizing CSRs in SSN transmission network of SSGs, still there is an issue of transients stabilities due to an occurrence of TPF in SSGs. Furthermore, with the additions of CSRs in SSN transmission network of SSGs, an equalized power sharing is achieved between $PG1$ (861.8 MW), $PG2$ (861.8 MW) and $PG3$ (861.8 MW) of cluster 1, i.e., refereed Table 1, Buses $B4$, $B8$ and $B12$ with operating (CSR 1 + CSR 2 +CSR 3) in SSN transmission network of SSGs. Whereas, for cluster 2, 3 and 4, there is still some deviations of $PG4$ (901.8 MW), $PG7$ (907.4 MW) and $PG10$ (901.8 MW) with respect to $PG5$ (861.8 MW) and $PG6$(861.8 MW), $PG8$ (913.8 MW) and $PG9$ (913.8 MW) and $PG11$ (902MW) and $PG12$ (902MW), i.e., refereed Table 1, Buses $B4$, $B8$, $B12$, $B28$, $B32$, $B36$, $B88$, $B92$, $B96$, $B61$, $B68$ and $B72$, with operating (CSR 1 + CSR 2 + CSR 3) in SSN transmission network of SSGs. In equation form, these randomness $R_G(t)$ can be expressed as,

$$\begin{aligned} R_{G_1}(t)(P_{G_1}(t)) &\neq R_{G_2}(t) \\ (P_{G_2}(t)) &= R_{G_3}(t)(P_{G_3}(t)) \end{aligned} \tag{54}$$

$$\begin{aligned} R_{G_4}(t)(P_{G_1}(t)) &\neq R_{G_5}(t) \\ (P_{G_2}(t)) &= R_{G_6}(t)(P_{G_3}(t)) \end{aligned} \tag{55}$$

$$\begin{aligned} R_{G_7}(t)(P_{G_1}(t)) &\neq R_{G_8}(t) \\ (P_{G_2}(t)) &= R_{G_9}(t)(P_{G_3}(t)) \end{aligned} \tag{56}$$

$$\begin{aligned} R_{G_{10}}(t)(P_{G_1}(t)) &\neq R_{G_{11}}(t) \\ (P_{G_2}(t)) &= R_{G_{12}}(t)(P_{G_3}(t)) \end{aligned} \tag{57}$$

Eq. 54 shows, that by incorporating CSRs in SSN transmission network of SSGs, randomness between $R_{G_1}(t)$, $R_{G_2}(t)$ and $R_{G_3}(t)$ is minimized, i.e., referred eq. 50.

Similarly, in order to compensate for smaller power outages of 10.8 MW in order to achieve an equalized power sharing between different power grid stations and their

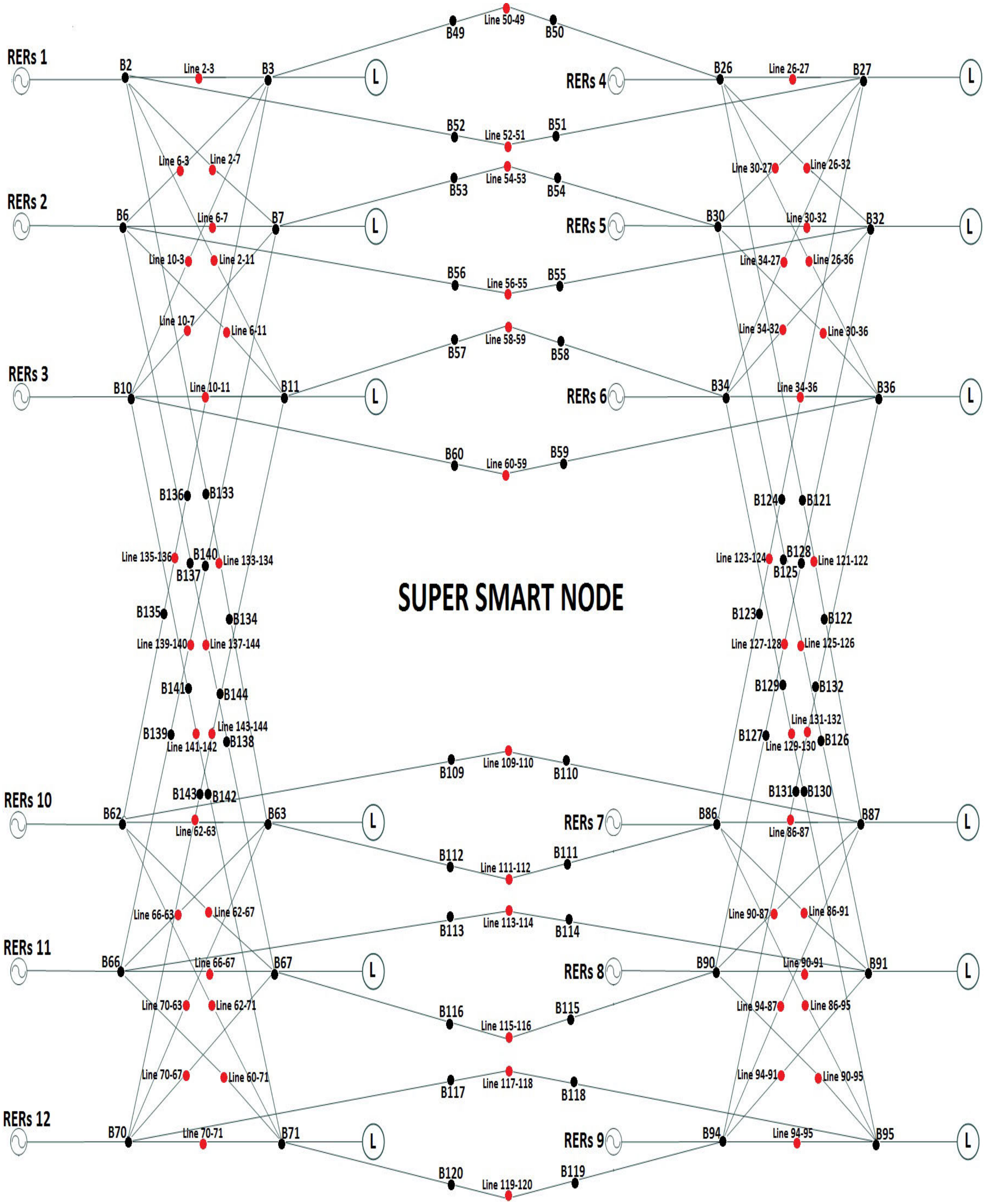
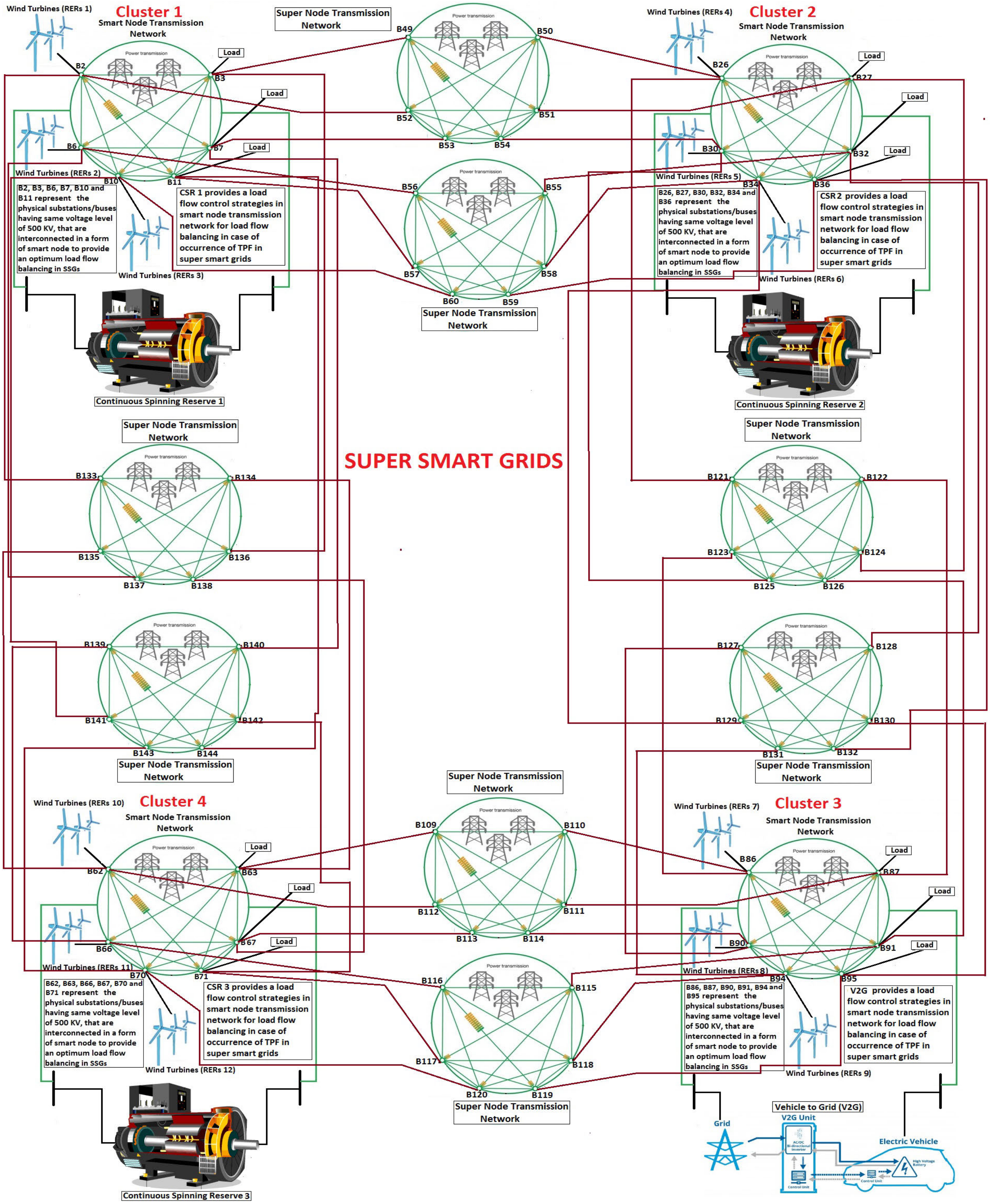


FIGURE 11. Topological model for Super Smart node.

corresponding clusters, integrated V2G in SSN transmission network isoperated along with CSR 1, 2 and 3. Simulation results in Fig. 21 verifies that due to an unexpected outage in terms of TPF at $t = 1s$ to $t = 1.1s$, a V2G kicks in the power system at t=1s and regulates the power system in terms of active power, i.e., Bus $B147$ active power graph, also referred



B2, B3, B6, B7, B10 and B11 represent the physical substations/buses having same voltage level of 500 KV, that are interconnected in a form of smart node to provide an optimum load flow balancing in SSGs

CSR 1 provides a load flow control strategies in smart node transmission network for load flow balancing in case of occurrence of TPF in super smart grids

B26, B27, B30, B32, B34 and B36 represent the physical substations/buses having same voltage level of 500 KV, that are interconnected in a form of smart node to provide an optimum load flow balancing in SSGs

CSR 2 provides a load flow control strategies in smart node transmission network for load flow balancing in case of occurrence of TPF in super smart grids

B62, B63, B66, B67, B70 and B71 represent the physical substations/buses having same voltage level of 500 KV, that are interconnected in a form of smart node to provide an optimum load flow balancing in SSGs

CSR 3 provides a load flow control strategies in smart node transmission network for load flow balancing in case of occurrence of TPF in super smart grids

B86, B87, B90, B91, B94 and B95 represent the physical substations/buses having same voltage level of 500 KV, that are interconnected in a form of smart node to provide an optimum load flow balancing in SSGs

V2G provides a load flow control strategies in smart node transmission network for load flow balancing in case of occurrence of TPF in super smart grids

FIGURE 12. Transmission Network of Super Smart node.

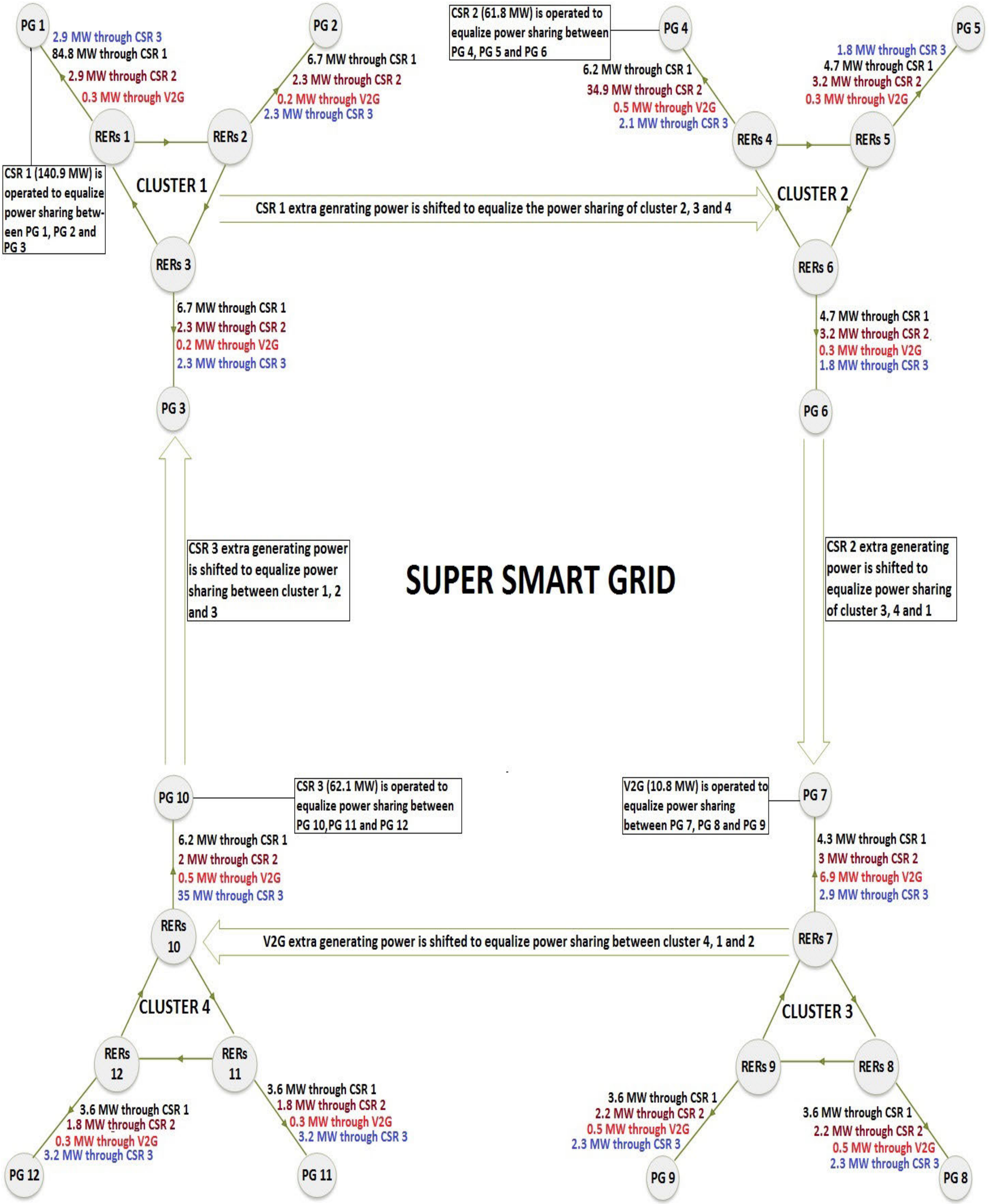


FIGURE 13. Load flow sharing of CSR 1, CSR 2, CSR 3 and V2G for each clusters and their corresponding power grid stations.

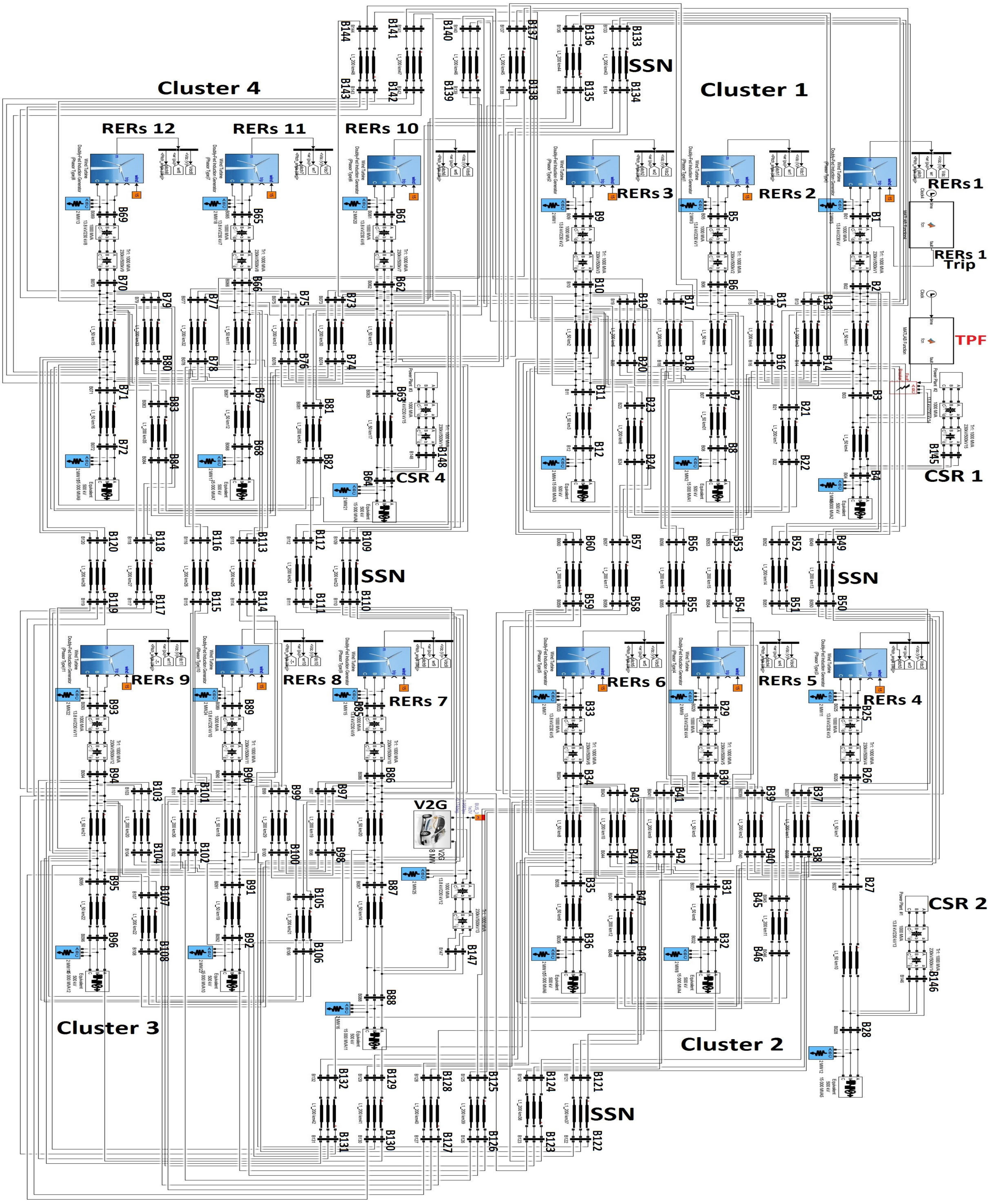


FIGURE 14. Super Smart node, CSR and V2G MATLAB schematic diagram.

TABLE 1. Active power on different buses.

CLUSTER 1					
GENERATING STATIONS (GS)					
Buses	GS 1	Buses	GS 2	Buses	GS 3
B1(TPF-No tripping of WT)	973.6	B5(TPF-No tripping of WT)	973.6	B9(TPF-No tripping of WT)	973.6
B1(TPF-Tripping of WT)	-2.51	B5(TPF-Tripping of WT)	973.6	B9(TPF-Tripping of WT)	973.6
RECEIVING STATIONS (RS)					
Buses	RS 1	Buses	RS 2	Buses	RS 3
B4(TPF) - SSN- No tripping of WT	952.7	B8(TPF)-SSN-No tripping of WT	952.7	B12(TPF)-SSN-No tripping of WT	952.7
B4(TPF) - SSN-Tripping of WT	771.2	B8(TPF)-SSN-Tripping of WT	850.6	B12(TPF)-SSN-Tripping of WT	850.6
B4(CSR 1)	856	B8(CSR 1)	857.3	B12(CSR 1)	857.3
B4(CSR 1+CSR 2)	858.9	B8(CSR 1+CSR 2)	859.6	B12(CSR 1+CSR 2)	859.6
B4(CSR 1+CSR 2+CSR 3)	861.8	B8(CSR 1+CSR 2+CSR 3)	861.8	B12(CSR 1+CSR 2+CSR 3)	861.8
B4(CSR 1+CSR 2+V2G+CSR 3)	**862.1**	**B8(CSR 1+CSR 2+V2G+CSR 3)**	**862.1**	**B12(CSR 1+CSR 2+V2G+CSR 3)**	**862.1**
CLUSTER 2					
GENERATING STATIONS (GS)					
Buses	GS 4	Buses	GS 5	Buses	GS 6
B25(TPF-No tripping of WT)	973.6	B29(TPF-No tripping of WT)	973.6	B33(TPF-No tripping of WT)	973.6
B25(TPF-Tripping of WT)	973.6	B29(TPF-Tripping of WT)	973.6	B33(TPF-Tripping of WT)	973.6
RECEIVING STATIONS (RS)					
Buses	RS 4	Buses	RS 5	Buses	RS 6
B28(TPF)-SSN-No tripping of	952.7	B32(TPF)-SSN-No tripping of	952.7	B36(TPF)-SSN-No tripping of	952.7
B28(TPF)-SSN-Tripping of WT	858.6	B32(TPF)-SSN-Tripping of WT	892.3	B36(TPF)-SSN-Tripping of WT	892.3
B28(CSR 1)	864.8	B32(CSR 1)	897	B36(CSR 1)	897
B28(CSR 1+CSR 2)	899.7	B32(CSR1+CSR 2)	900.2	B36(CSR 1+CSR 2)	900.2
B28(CSR 1+CSR 2+CSR 3)	901.8	B32(CSR 1+CSR 2+CSR 3)	902	B36(CSR 1+CSR 2+CSR 3)	902
B28(CSR 1+CSR 2+V2G+CSR 3)	**902.3**	**B32(CSR 1+CSR 2+V2G+CSR 3)**	**902.3**	**B36(CSR 1+CSR 2+V2G+CSR 3)**	**902.3**
CLUSTER 3					
GENERATING STATIONS (GS)					
Buses	GS 7	Buses	GS 8	Buses	GS 9
B85(TPF-No tripping of WT)	973.6	B89(TPF-No tripping of WT)	973.6	B93(TPF-No tripping of WT)	973.6
B85(TPF-Tripping of WT)	973.6	B89(TPF-Tripping of WT)	973.6	B93(TPF-Tripping of WT)	973.6
RECEIVING STATIONS (RS)					
Buses	RS 7	Buses	RS 8	Buses	RS 9
B88(TPF)-SSN-No tripping of WT	952.7	B92(TPF)-SSN-No tripping of	952.7	B96(TPF)-SSN-No tripping of	952.7
B88(TPF)-SSN-Tripping of WT	897.2	B92(TPF)-SSN-Tripping of WT	905.7	B96(TPF)-SSN-Tripping of WT	905.7
B88(CSR 1)	901.5	B92(CSR 1)	909.3	B96(CSR 1)	909.3
B88(CSR 1+CSR 2)	904.5	B92(CSR 1+CSR 2)	911.5	B96(CSR 1+CSR 2)	911.5
B88(CSR 1+CSR 2+CSR 3)	907.4	B92(CSR 1+CSR 2+CSR 3)	913.8	B96(CSR 1+CSR 2+CSR 3)	913.8
B88(CSR 1+CSR 2+V2G+CSR 3)	**914.3**	**B92(CSR 1+CSR 2+V2G+CSR 3)**	**914.3**	**B96(CSR 1+CSR 2+V2G+CSR 3)**	**914.3**
CLUSTER 4					
GENERATING STATIONS (GS)					
Buses	GS 11	Buses	GS 12	Buses	GS 13
B61(TPF-No tripping of WT)	973.6	B65(TPF-No tripping of WT)	973.6	B69(TPF-No tripping of WT)	973.6
B61(TPF-Tripping of WT)	973.6	B65(TPF-Tripping of WT)	973.6	B69(TPF-Tripping of WT)	973.6
RECEIVING STATIONS (RS)					
Buses	RS 10	Buses	RS 11	Buses	RS 12
B64(TPF)-SSN-No tripping of	952.7	B68(TPF)-SSN-No tripping of	952.7	B72(TPF)-SSN-No tripping of	952.7
B64(TPF)-SSN-Tripping of WT	858.6	B68(TPF)-SSN-Tripping of WT	892.3	B72(TPF)-SSN-Tripping of WT	892.3
B64(CSR 1)	864.8	B68(CSR 1)	897	B72(CSR 1)	897
B64(CSR 1+CSR 2)	866.8	B68(CSR 1+CSR 2)	898.8	B72(CSR 1+CSR 2)	898.8
B64(CSR 1+CSR 2+CSR 3)	901.8	B68(CSR 1+CSR 2+CSR 3)	902	B72(CSR 1+CSR 2+CSR 3)	902
B64(CSR 1+CSR 2+V2G+CSR 3)	**902.3**	**B68(CSR 1+CSR 2+V2G+CSR 3)**	**902.3**	**B72(CSR 1+CSR 2+V2G+CSR 3)**	**902.3**

Table 1, i.e., Buses $B4$, $B8$, $B12$, $B28$, $B32$, $B36$, $B88$, $B92$, $B96$, $B61$, $B68$ and $B72$ active power with operating (CSR 1 + CSR 2 + V2G + CSR 3) in SSN transmission network of SSGs. Table 1 shows, that with operating V2G at cluster 3, an equalized power sharing is achieved between ($PG1$ (862.1 MW), $PG2$ (862.1 MW) and $PG3$ (862.1 MW))

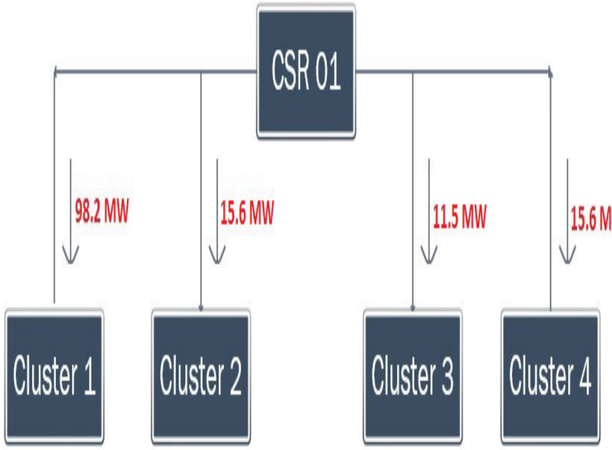


FIGURE 15. CSR 01 active power transfer to different clusters.

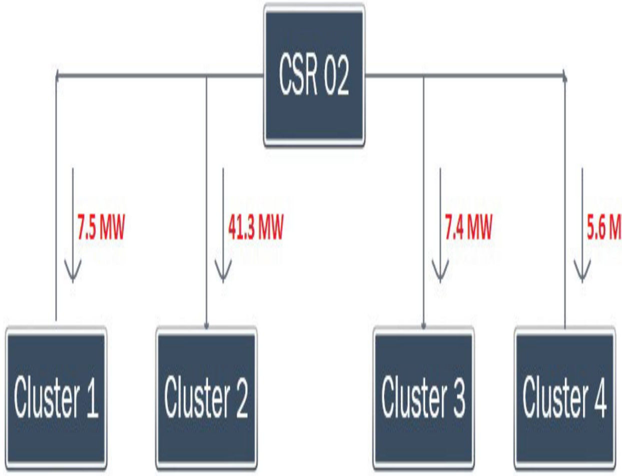


FIGURE 16. CSR 02 active power transfer to different clusters.

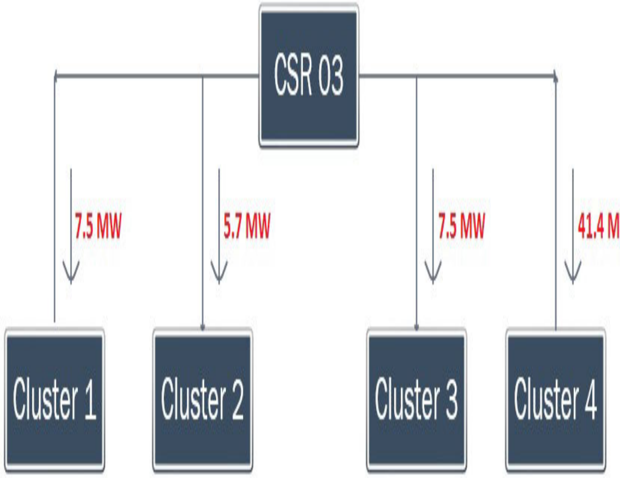


FIGURE 17. CSR 03 active power transfer to different clusters.

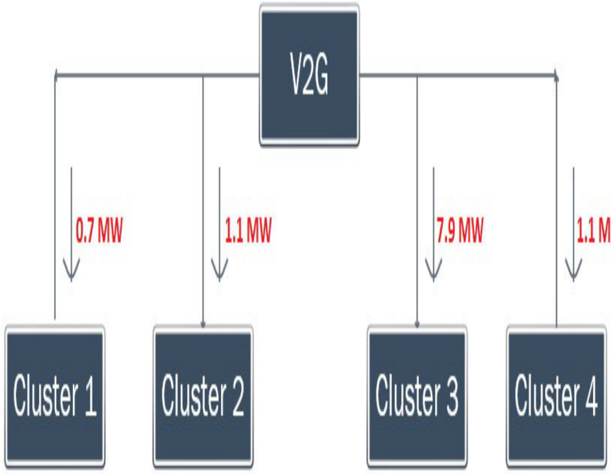


FIGURE 18. V2G active power transfer to different clusters.

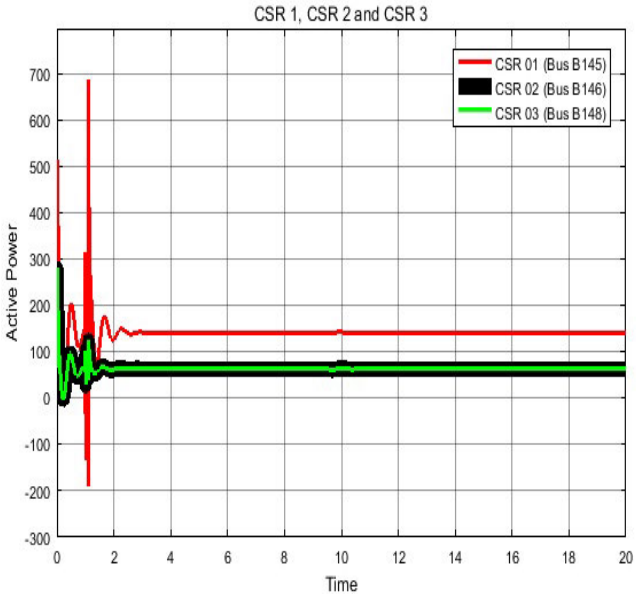


FIGURE 19. Bus B145, B146, B148 active power graphs.

of cluster 1, (*PG*4 (902.3 *MW*), *PG*5 (902.3 *MW*) and *PG*6 (902.3 *MW*)) of cluster 2, (*PG*7 (914.3 *MW*), *PG*8 (914.3 *MW*) and *PG*9 (914.3 *MW*)) of cluster 3, (*PG*10 (902.3 *MW*), *PG*11 (902.3 *MW*) and *PG*12 (902.3 *MW*)) of cluster 4. Through utilizing V2G along with CSRs in SSGs, finally the randomness $R_G(t)$ between different power grid stations of each cluster is minimized, i.e., equalized load flow sharing between different power grid stations of each cluster in SSGs is achieved, i.e., Eqs. 54, 55, 56 and 57 will becomes,

$$\begin{aligned} R_{G_1}(t)(P_{G_1}(t)) &= R_{G_2}(t) \\ (P_{G_2}(t)) &= R_{G_3}(t)(P_{G_3}(t)) \end{aligned} \tag{58}$$

$$\begin{aligned} R_{G_4}(t)(P_{G_1}(t)) &= R_{G_5}(t) \\ (P_{G_2}(t)) &= R_{G_6}(t)(P_{G_3}(t)) \end{aligned} \tag{59}$$

$$\begin{aligned} R_{G_7}(t)(P_{G_1}(t)) &= R_{G_8}(t) \\ (P_{G_2}(t)) &= R_{G_9}(t)(P_{G_3}(t)) \end{aligned} \tag{60}$$

$$R_{G_{10}}(t)(P_{G_1}(t)) = R_{G_{11}}(t)$$

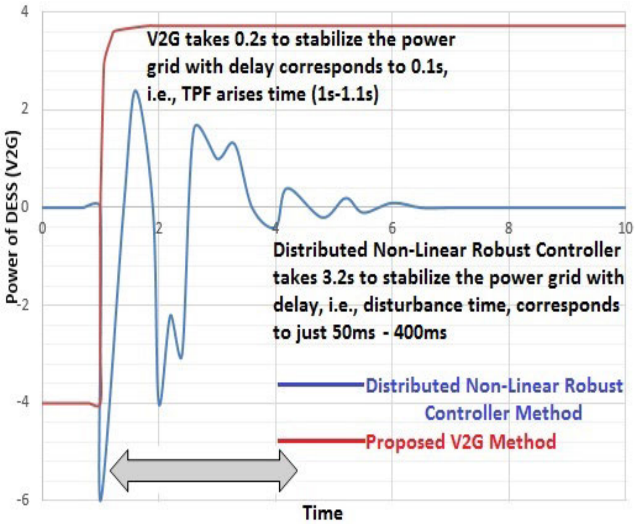


FIGURE 20. Comparison analysis between controller and V2G method.

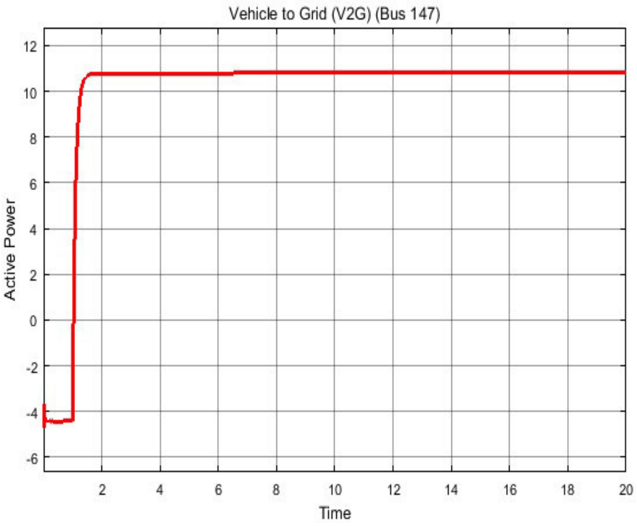


FIGURE 21. Bus B147 active power graph.

$$(P_{G_2}(t)) = R_{G_{12}}(t)(P_{G_3}(t)) \tag{61}$$

Simulation results of V2G show that in spite of an outage of $t = 0.1s$,. The main advantage of V2G over CSRs is that it manages the power systems quickly and without any transient problems. Furthermore, V2G cooperative control based probabilistic modeling shows effective results, in terms of accommodating power outage and transients issues in SSGs as compared to CSR non cooperative control based probabilistic modeling as shown in Fig. 26, i.e., comparison analysis of CSR 1, CSR 2 and CSR 3 with V2G. Moreover, by utilizing V2G cooperative control strategies in SSGs, the coordination problem in terms of an equalized power sharing and transients stability enhancement between different power grid stations and their corresponding clusters of SSGs, under high penetration of renewable generation is easily achieved. This observation can be further verified by comparing our proposed distributed cooperative control based approach of V2G technology with the proposed distributed controller based approach in [104], as in case of SSGs. As illustrated in Fig. 20, the V2G cooperative control based strategies can achieve transient stability enhancement within around $0.2s$, considering latencies up to $0.1s$, i.e., TPF arises time $(1sto1.1s)$ in SSGs. The distributed non linear robust controller achieves the same performance, but it will take some time to achieve transient stability enhancement of power gird, i.e., around $3.2s$ as shown in Fig. 20, when the latency rate is just $50ms - 400ms$. These results verified the effectiveness of V2G cooperative controller based technique in terms of compensating transient stability issues in SSGs, even considering the high latency rate of upto $0.1s$, i.e., TPF arises time and even more.

Fig. 22, Fig. 23 and Fig. 24 identify the effect of transients arises due to an occurrence of TPF on a synchronized transmission network in a form of SSN, when CSR 1, CSR 2 and CSR 3 are operated in order to achieve a load flow balancing on the receiving side of cluster 1, cluster 2 and cluster 4 of different power grid stations in SSGs. Although CSR 1, CSR 2 and CSR 3 provides an efficient load flow balancing on the receiving side of different power grid stations, but the effect of transients in terms of TPF introduces different power quality issues in these CSRs, which is its major disadvantage as compared to V2G. Moreover, the delays in terms of transients in CSR 1, CSR 2 and CSR 3 is shown in Fig. 24, that observed the pattern of Normal distribution.

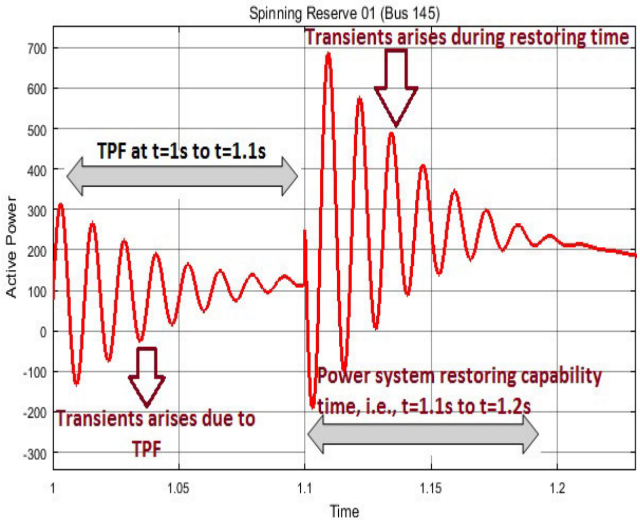


FIGURE 22. Bus B145 transients graph.

Fig. 25 shows the effect of load flow balancing and transient stability improvement in the context of active power along with addition of V2G in cluster 3 receiving side power grid stations. It is evident from Fig. 25, that V2G cooperative control base model will only operates, when TPF arises in a SSG due to any type of power quality disturbances, due to which it provides a cost effective solution, in terms of

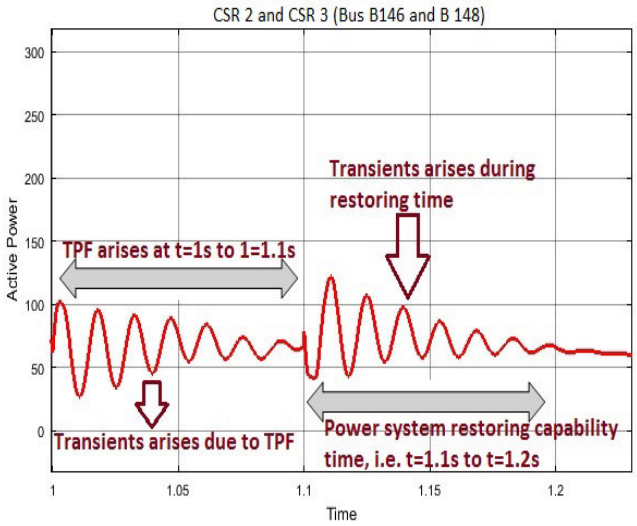


FIGURE 23. Bus B146, B148 transients graph.

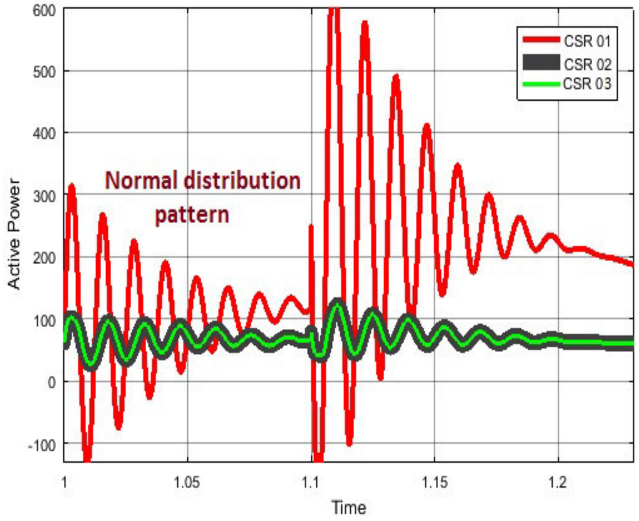


FIGURE 24. Bus B145, B146 and B148 distribution pattern graphs.

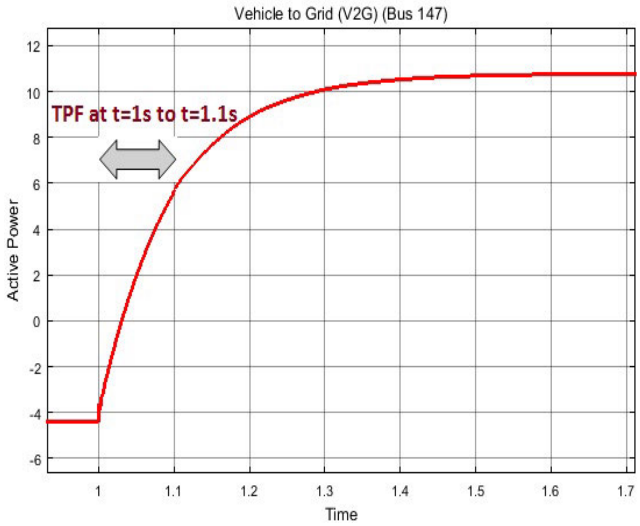


FIGURE 25. Bus B147 transients graph.

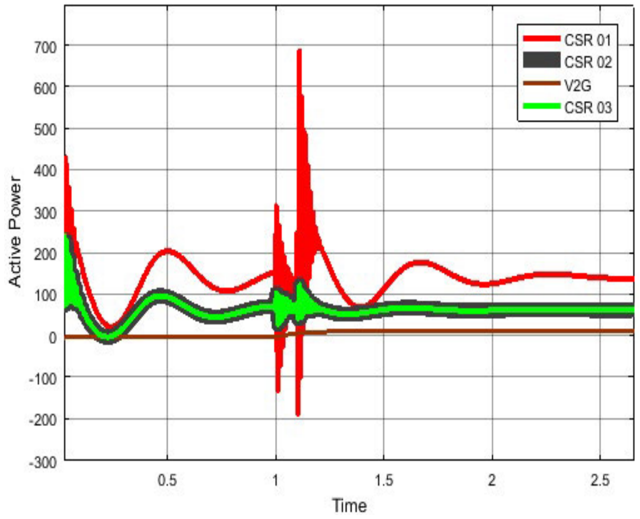


FIGURE 26. Buses B145, B146, B147 and B148 transients graphs.

load flow balancing and transients stability improvement as compared to CSR 1, CSR 2 and CSR 3 non cooperative control based model, which are continuously operated. This is due to the reason of transmission of information between different clusters of SSGs in case of any disturbance arises in power systems, i.e., fault occurrence time, which is available to power system operators, especially in case of cooperative control model of V2G as compared to CSRs non cooperative control based model, which are continuously operated and has limited information related to fault behavior on different clusters, as in case of an occurrence of TPF in SSGs. It is evident from time $t = 1s$, i.e., TPF arises time, where V2G is operated as shown in Fig. 25. Moreover, there is no transients issues arises, when V2G is utilized in order to achieve a synchronous stability in terms of load flow balancing between different clusters of SSG. These results can be further verified in terms of graphical comparison analysis between CSR 1, CSR 2, CSR 3 and V2G as shown in Fig. 26. The whole single line diagram of the SSGs is illustrated in Fig. 27.

IV. COUNTRIES MOVING TOWARDS SUPER SMART GRIDS

Super grid of the transmission side takes an edge over smart grid in terms of utilizing renewable and clean power generation scattered over a wide area of network with longer distances and therefore supply large amount of power generation into different power grid stations. Smart grid on the other hand provides benefit to customers in terms of saving electricity and sell their excess renewable power generation to the national grid. SSG takes advantages of both technologies, i.e., super and smart grid in order to efficiently integrates different RERs. However, considering todays demand requirements

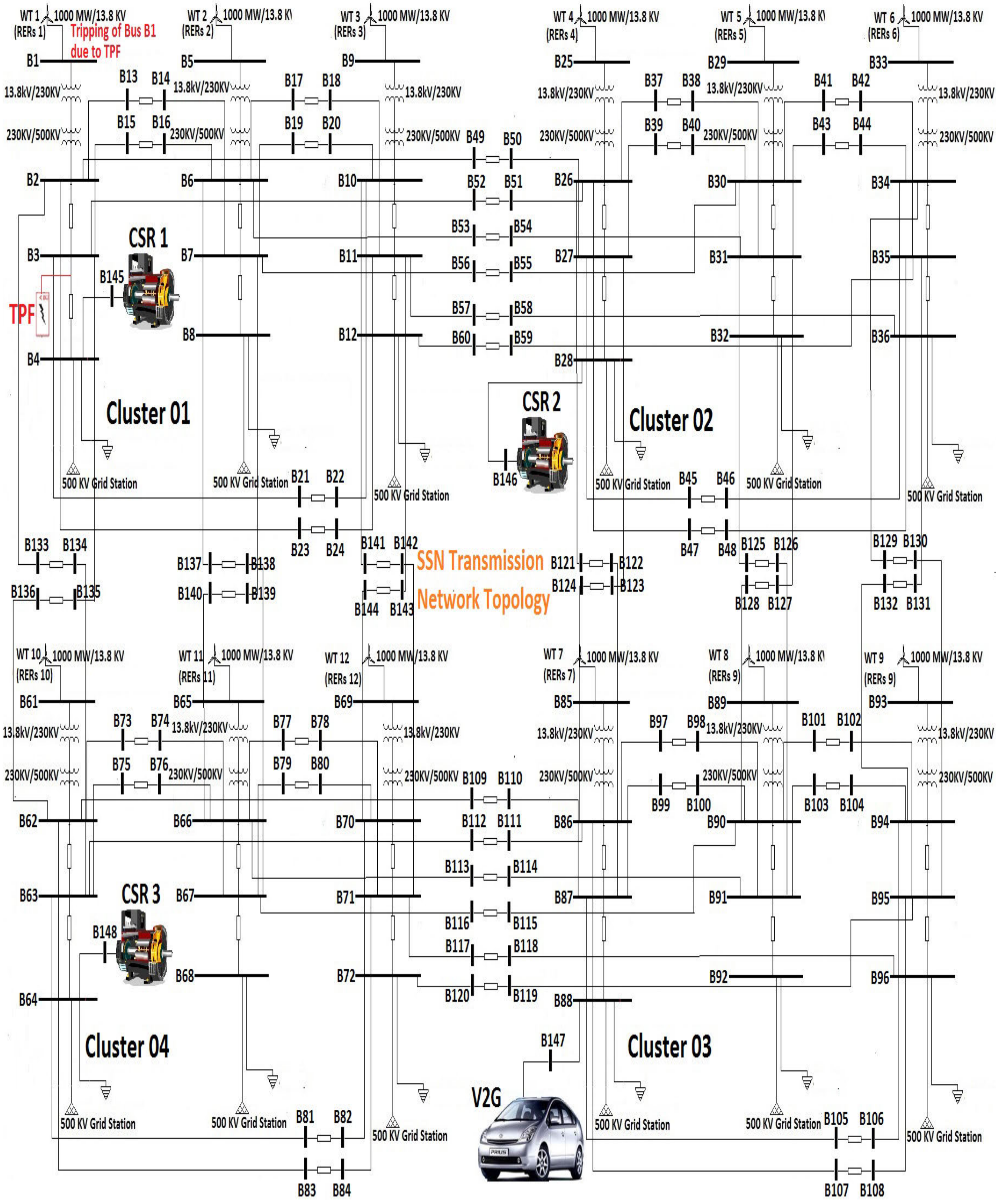


FIGURE 27. Single line diagram of SSGs.

worldwide, smart grids does not fit in a commonly accepted definition of power planning infrastructure. Due to this reason, some of the countries takes initiatives to devised their diverse blueprints for the development of SSGs according to their specific national conditions and demand requirements of their power grid stations. For instance, the united states are moving towards transforming their existent grid infrastructures by utilizing clean energy and wide use of plug in hybrid electric vehicles as proposed in [133]. European countries as already discussed retrofitting existent grid infrastructures through utilizing different RERs in order to reduce CO_2 emissions [4]. Japan tackles the problem of energy crisis through utilizing large scale dispersed PV power in a form of SSGs as discussed in [134]. SAARC countries on other hand in collaboration with SAARC energy center Pakistan demonstrates different projects as proposed in [135] and [136] in order to provide a valuable resource in terms of planning and development of future SAARC SSGs, that will improvise the electrical infrastructure in terms of power sharing between different SAARC countries. Thus, for the purposes of this paper, SSG is considered to ba a valuable resource, that should be economically accepted in terms of transmitting renewable power from the supply side and also operating efficient power plants from the demand side.

V. RISKS AND OPEN QUESTIONS IN CASE OF FUTURE SSGs VISION

The literature point of review based on a scenario of a future SSG vision clearly identifies the significant benefits of an importing large amount of electrical energy from North Africa based on a massive renewable energy resources, i.e., consider the proposed case studies of gregor czisch [137], [138], [139], the german aerospace center [140], [141], [142] and DESERTEC [143], [144]. All of these case studies concludes the fact, that an electricity imports from North Africa based on RERs will be considered to be much cheaper than the electricity production in a current state, even including transmission scattered over a wide area of network and/or a decentralized power energy system as proposed in [145], [146], [147], and [148], which includes the significance of a decentralized energy systems with the ability to provide two way flow of information between utility and consumers enables an optimum utilization of RERs for load management systems. These case studies concludes the fact, that implementing the future SSG vision is considered to be challenging with respect to technologically and economically perspective but it is also realistic. From literature resources, the main hurdle behind the future vision of developing SSG is a political and most importantly a financial problem as proposed in [149] survey results.

VI. TECHNOLOGICAL UNCERTAINTIES

Inspite of an investment and financial problems as discussed above, there are still several technological questions, which must be answered to clarify the vision of developing a future SSGs power infrastructure. Among these questions, high voltage direct current (HVDC) transmission system is of current interest. HVDC lines have been significantly utilized over a past decade. However, the main drawback in HVDC technology is that, commutation failures occurs at the inverter stations due to different types of power system disturbances, which have been significantly experienced by the power systems. Moreover, in order to reduce the risks of collapsing AC voltages and addressing an issues of power system instability, developing and testing of several power controls mechanisms, which are capable of handling different parallel schemes, such as regulation, coordination and also accommodates an interchange power control mechanisms among different RERs is necessary to be carried out as proposed in [150]. Due to available smart technologies, the remotely operation of a modern HVDC links can be easily performed. Such operations will provides a strengthen capability to power grid in terms of reliability and stability, i.e., provides a strong protection to the control units in order to reduce problems to be further cascaded down. However, the development of a protection and control scheme based on a multilayer technology, which interconnects different local measurement devices and also an incorporation of an advanced level control schemes into an overall control strategy as proposed in [4] is far from being fully developed or implemented. Virtual Power Plants (VPP) developing and demonstrations is a major future step which needs to be taken as an initiative to develop future SSGs. VPPs can acts as a neutral systems, which can be easily operated with utilizing different diverse energy sources, but incorporating VPPs smart grid approaches in SSGs is still in their pioneering phases [151].

Moreover, due to early stages of development of V2G technology in order to provide electrical energy to power grid stations and also considering the phenomena of an electro mobility with plug in hybrids vehicles, it is difficult for power system engineers to utilized these technologies in SSGs. Therefore detailed simulation studies regarding an incorporating V2G technology in SSGs is essential to be carried out before it's actual implementation in future, which is the main research objective of this research work. Similarly form technology portfolio point of view, the relative weight of storage and smoothing technologies will only become suitable in the process of setting up smart power infrastructure and it is highly uncertain and difficult task to utilized these technologies in future SSGs power infrastructures. The relative weight of smoothing technologies and storage itself in relation to stochastic smoothing from a wide area use of renewable will totally depend on the weights given to the super and the smart part of the SSG power infrastructure, respectively.

VII. LOOKING AHEAD (EUROPEAN SUPER SMART GRID)

The EU renewables directive will defined a set of certain boundaries for the different member states of the Europe to take initiatives in order to reached 20 % Moreover, the large scale investments is required in an upcoming few years, especially for the construction of a concentrating solar thermal plants (CSP) in the deserts of North Africa and on the Iberian Peninsula, along with the investments of developing of an onshore and offshore wind farms, as already proposed by the French EU presidency. Through utilizing CSP, the solar plan based on a Mediterranean region foresees 20 GW of RERs capacity in that region by 2020. If all of this capacity were totally based on CSP technology with the addition of overnight storage systems, this could lead to a power production of approximately 80100 TWh/a. This would reduce 80100 Mt CO2 emissions in environment, considering the power production from coal is replaced, which would be considered to be a significant step in order to achieved green energy target compliance in Europe. More importantly, by achieving power production of 20 GW CSP in the next few years would reduce technological and commercial uncertainties, thus proving a promising way for investors to invest their money in renewable electricity generation and transmission systems based on SSGs. Achievements in the RERs field until 2020 will provides further paths for defining future steps needed for shaping the European energy system in terms of achieving the 80 %

VIII. CONCLUSION

SSGs may be susceptible to significant power quality disruptions because of their congestion and scalability problems. In order to identify the irregularity between generation and demand phenomena in the case of SSGs, particularly in terms of the occurrence of TPF, probabilistic modelling in terms of SSN, V2G cooperative control, and CSRs non cooperative control based models have been presented. On the receiving side of various power grid stations, these probabilistic modelling approaches decrease power outages and transient stability problems while effectively balancing the load flow. Additionally these modelling tools greatly increase the accuracy of taking the required steps to effectively prevent future SSG related TPF instabilities. Using the aforementioned probabilistic modelling, the synchronization of complex networks (SSG) is used to examine the dynamic behavior of V2G in terms of load balancing and transient stability. Model based simulation results demonstrated that the suggested load flow balancing and transient stability technique may be used to implement synchronous stability of demand levels in various clusters by achieving synchronous stability of various power grid stations in SSGs. Moreover, the conclusions of probabilistic modelling and simulation demonstrate that the technology based on V2G cooperative control can effectively balance load flows and minimize the problem of transient stability across various clusters in SSGs, and further optimizes the power demand performance more efficiently as compared to utilizing non cooperative control based CSRs approach and distributed controller based approach in SSGs.

IX. FUTURE TECHNICAL ADVANCEMENT IN THIS PAPER

This paper primary mentioned the situations of utilizing V2G cooperative controller based technique for compensating small power outages in SSGs due to its high cost, which includes battery degradation, the requirement for active interaction between the grid and the vehicles, impacts on grid distribution networks, modifications to the infrastructure, and economic, political, ideological, and technological barriers. These limitations will make V2G is attractive fields in terms of its applicability to settled the larger power outages in SSGs. V2G implementation is expected to be more cost effective for both power companies and vehicle owners, even if it may mitigate the lifespan of plug in EVs. Moreover, EV batteries will be less expensive owing to mass manufacture in the future, making V2G a more viable option for compensating greater power outages in SSGs, and therefore eliminate the concept of utilizing CSRs in SSGs, as it provides more efficient results for load flow balancing and transient stability as compared to CSRs. Moreover, the proposed method is formulated and presented to select the optimal control mode in a form of SSN, CSRs and V2G in order to provide an equalized load flow sharing between different power grid stations of each clusters, i.e., cluster 1 (862.1 MW), cluster 2 (902.3 MW), cluster 3 (914.3 MW) and cluster 4 (902.3 MW). This method can be further extended to provide an equalized load flow sharing between all clusters and their corresponding power grid stations, i.e., as in our case different power grid stations of cluster 2 and 4 received the same power at the receiving side, therefore it can be easily extended for all 4 clusters in SSGs. Furthermore, in future, through probabilistic modeling of SSN transmission network for SSGs, we can also adjust the load flow sharing between different clusters in SSGs, according to their required demand load conditions. A scientific work based on a small potion of this idea for load flow balancing in power systems according to required demand conditions through using a smart node transmission network topology in case of smart grids was already proposed in [15]. Moreover, in this paper, our cooperative control strategy of load flow balancing and transients stability using V2G in SSGs does not take into an account certain aspects, i.e.,

1) EVs availability at a time of need.
2) The customer participation programs, which also plays an important role in an improving of overall power grids stability.
3) The load flow balancing using V2G under the constraints of EVs mobility is also considered to be the one of an important aspect.

These issues can be further highlighted in Sec. X-I and Sec. X-J. The computational environment for management and control of power in many clusters of SSGs as shown in Fig. 28. The smooth operations for controlling of power can be managed by SCADA. Every cluster in SSGs have own control center that communicate with other cluster through SCADA.

X. UNSOLVED PROBLEMS AND TECHNIQUES NEED FURTHER RESEARCH

In this section, we focused on some of the activities that should be considered by the governments, utility companies,

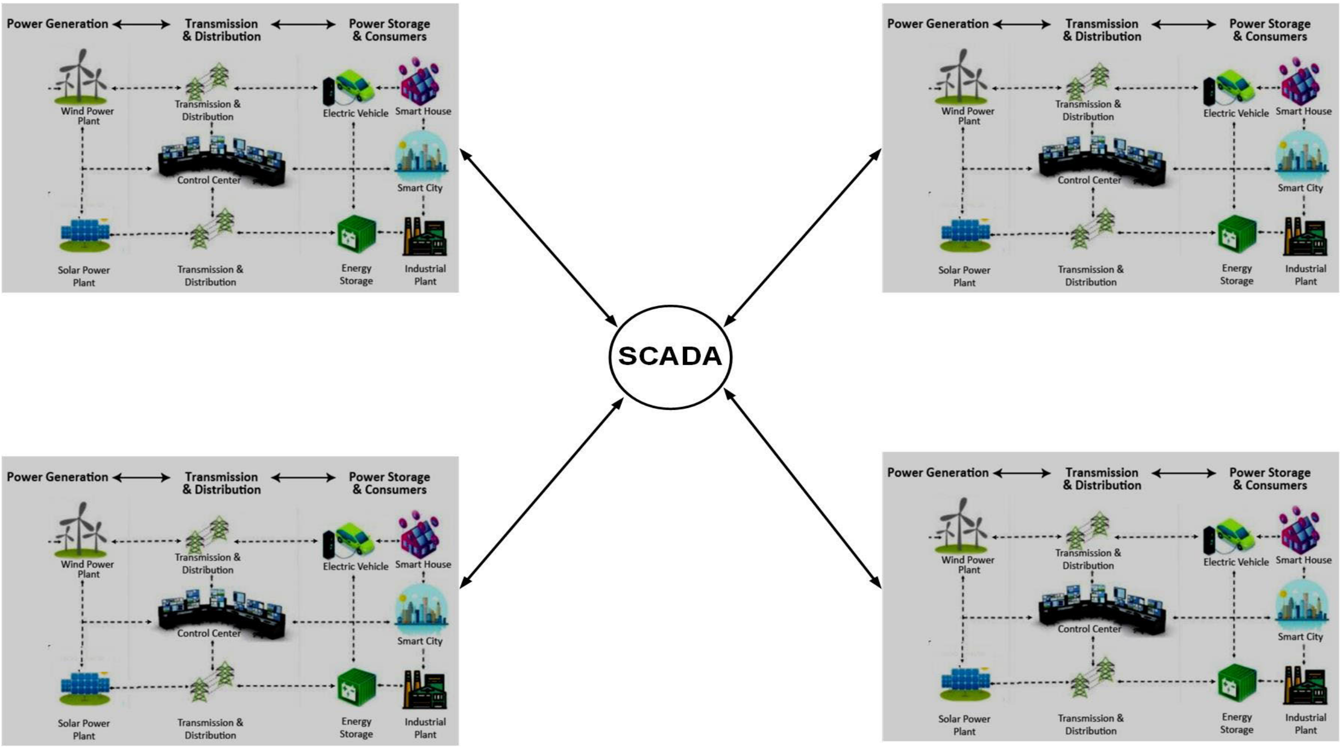


FIGURE 28. Control block diagram of SSG.

regulators and technology firms to make meaningful progress toward the future development of SSGs power infrastructure.

A. FUTURE TRANSMISSION SYSTEMS

As, SSGs power infrastructure is based on long transmission lines, therefore a considerable amount of losses occurred due to the resistance of the wires and the equipments through which electricity passes. Considering this scenario, SSGs transmission infrastructure will be updated. New technologies will be incorporated in a power systems, such as flexible AC transmission system (FACTS) can be utilized for maximizing the power transfer capabilities in SSGs. HVDC technology can be utilized for the integration of different RERs, which can significantly reduces transmission losses as compared to HVAC transmission lines. Dynamic line rating (DLR) can be considered as a promising solution to identify the carrying capabilities of transmission network parts in order to prevent an overloading conditions. Moreover, high temperature superconductors (HTS) can be utilized to decrease the considerable amount of transmission losses.

B. COMPLICATED DECISION MAKING PROCESS IN CASE OF SSGs

In order to provide a proper assessment of a failures probabilities in case of a SSGs power infrastructure, we must have to considered and solves an algorithms based on a much more complex decision problems keeping these failure probabilities in mind, but with in a shorter span of time as proposed in [152], [153]. As we already discussed that a commercial future SSGs power infrastructure may have a large number of nodes, therefore realizing these failure probabilities with respect to each node will be considered to be a challenging research issue. A possible solution to overcome these critical situations is to utilize such a power system network that is totally based on a distributed decision making process. Means, that a different number of failure controllers with each having its own capabilities could be placed in the SSGs power infrastructure at a different places, which are more vulnerable to any kind of power system disturbances. Each of the controller should takes care of different devices at the same time and therefore makes a suitable decisions locally based on different disturbances in power systems. This can correspondingly increases an accuracy in case of a decision making process and therefore reducing an overall failure probabilities response time in SSGs. However, an optimal locally decision making process is not always considered to be globally optimal. Therefore, we need to address properly the critical issues regarding, how to manage a balancing between the power system response time and the effectiveness of the local decision making process.

C. IMPACT OF AN INCREASING IN ASSET UTILIZATION AND ENERGY CONSUMPTION OF THE CUSTOMERS

The different modern power grid stations are operating at the near edge of its comfortable operation in most of the cases and more often because of the reason of an increasing in energy consumption of the users and especially by considering a methodology from the utility side, which involves an increasing in asset utilization by the customers, i.e., electrical energy as much as possible through utilizing a modern tools and techniques as proposed in [152], [153]. Due to this reason, the power system reliability risk are correspondingly increases, especially in case of SSGs, which is purely based on unreliable RERs. Therefore, in order to reduce the power system reliability risks, as in case of SSGs, there is a need to develop an optimize reliability approaches, through which a power system operators can find out the reliability margins in advance in power systems, so in order to provide a reliable operation to an overall power system network. Secondly, to observe dynamically the reliability margins, the power system operators needs a real time monitoring methods to be utilized in a power system network. In addition, as previously discussed, that maximizing the asset utilization could significantly minimizes the reliability margins and hence increasing the probability of power system failure. Therefore, we must have to balance the asset utilization and the corresponding risk increases through it.

D. INTEROPERABILITY

Since, SSGs is based on the interconnectivity of different technologies with one another, i.e., HVAC, HVDC, FACTS devices, etc. Therefore interoperability becomes a challenging research issue to make a SSGs power infrastructure properly work, in order for different components of the SSGs might coexist with interconnection between many heterogeneous standard and technologies. The general distribution network of HVDC system for different area is illustrated in Fig. (29).

E. INTERDISCIPLINARY

The involvement of different organizations and societies in case of developing a future SSGs power infrastructure will make the SSGs research areas an interdisciplinary in nature. For example, the integration of wireless sensor networks, actuators and communication networking technologies with power systems infrastructure. Moreover, incorporation of different cooperative control strategies with one another and also an integration of security protocols in power systems are one such issues receiving much attentions, as in case of SSGs power infrastructure.

F. TESTBED

Testbeds of SSGs are important and essential for conducting future research and test results.

G. DEMAND RESPONSE PROGRAMS FOR V2G

Considering the utilization of V2G technology in SSGs, The implementation of V2G demand policy responses will be the main focus of upcoming work in order to more effectively modify the dynamics of V2G, as suggested in [154]. In other words, by giving the power grid and the EVs greater flexibility, these demand response may be efficiently used to enhance the integration of EVs into future SSGs power infrastructure.

H. DYNAMICS OF THE POWER SYSTEM USING V2G

According to the theory presented [154], voltage dips are unavoidable when using V2G applications in SSGs. There haven't been many studies that take into account weak grid dynamics depending on V2G applications, despite their importance. Similarly, one of the excellent representation models that requires the consideration of weak grid scenarios is the integration of a sizable number of RERs into the power system, as in the case of SSGs, such as wind and solar energy sources with the inclusion of V2G technology. A thorough knowledge of the dynamic behaviors of the electric grid is essential to predicting the efficient and reliable functioning of the electric grid with V2G technology. The Fig. 30 depicts the concept of V2G technology and communications of vehicle with Every thing (V2X), while every thing represent the home, grid or another object. For transmission of DC power the DC-DC converter is required for interfacing purpose between grid and vehicle.

I. EVs OPTIMIZATION PROGRAMS UNDER CUSTOMER REQUIREMENT CONSTRAINTS

Another future research work using EVs technology in SSGs is considering the EVs optimization problem, especially under the constraints of customer requirements. Customers requirements can be as, the requirement for consumers to charge their electric vehicles batteries to the required state of charge (SOC) prior to departing. This is considered to be the most significant objective, which must be incorporated in EVs optimization programs, due to the fact that EV customers are often more eager to engage in the charge management program and supply electrical energy to utility, i.e., V2G only, if the customer EVs are fully charged when needed.

J. DEMAND RESPONSE MANAGEMENT USING V2G CONSIDERING EVs MOBILITY

Another important aspect is considering the network model of V2G energy network to performed DRM under the constraints of EVs mobility. This idea of DRM using V2G, considering EVs mobility was well defined for several districts in [55] for the case scenario of smart grids. This idea can be easily extended to SSGs, where we consider the scenario of DRM using V2G under the constraints of EVs mobility for different countries.

K. PERFORMANCE

SSGs power infrastructure is a very complex due to heterogeneous network systems, large scale deployments, interdisciplinary research areas, i.e., control, communication, power, etc., and also due to consisting of various dynamic and non-deterministic power systems. Therefore, efficiency is a very important terms in case of SSGs power infrastructure, that need to be properly addressed in order to provide better, fast,

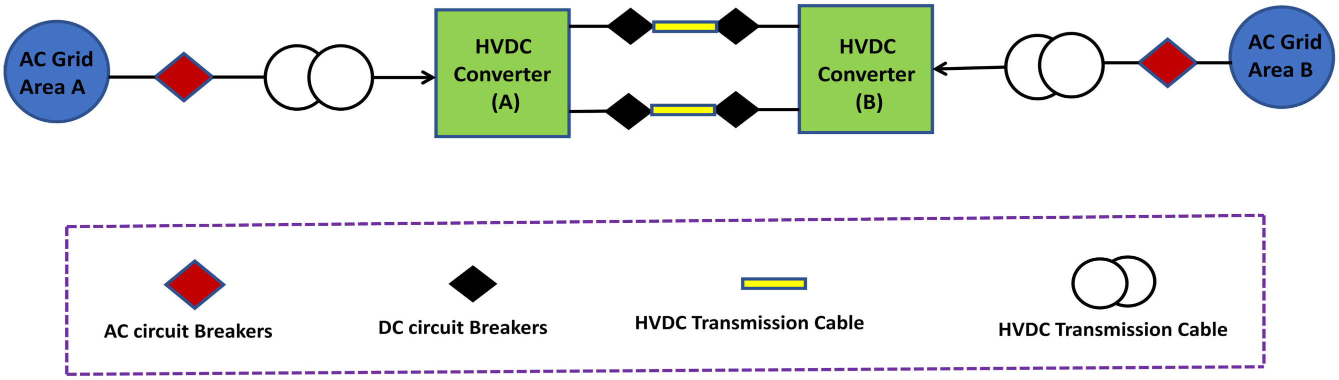


FIGURE 29. Components for transmission of HVDC system.

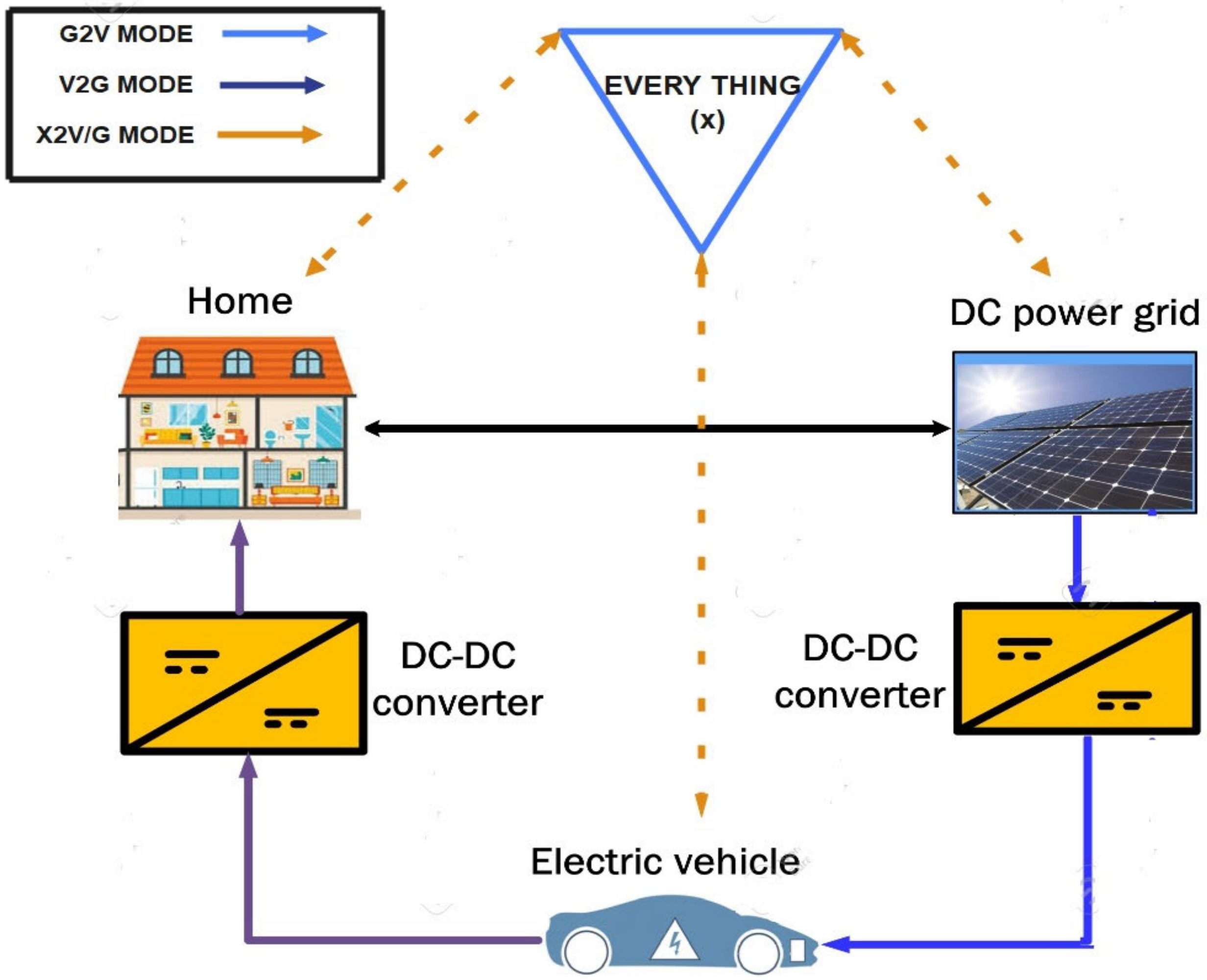


FIGURE 30. Flow of energy in different modes.

secure, robust controls and performing reliable operations in SSGs.

L. ENERGY MANAGEMENT TECHNOLOGIES ON SSG

The main role of these technologies to control and manage the flow of energy along with distribution of power according to the requirements of the load. The following wireless and wired technologies that can be used for management of power in SSGs [155].

1) ZIGBEE WIRELESS TECHNOLOGY

The usage of power in Zigbee wireless technology is very low which is major advantages of Zigbee. It's mostly used for high level application and based on IEEE 802.15.4 specification.

The infrastructure of Zigbee consist of six layers as shown in Fig. (31) [156].

Zigbee has a range of 30–50 m and operates in the 2.4–915 MHz frequency band; despite its small range and low data rate, it can still send data at up to 250 Kbps. It is a popular choice for smart grids since it enables providers to transmit and receive signals [157].

2) WIRELESS MESH

Wireless mesh is the major components of smart grid structure due to safety and effectively communicate the power distribution in smart grid system [158]. Wireless access points are used by a wireless mesh network (WMN) to create connections inside a network infrastructure. The distinctiveness of WMN lies in its decentralization and straightforward permission of message transmission to only the subsequent nodes rather than taking into account the complete network from the starting state. To efficiently and effectively reach the whole network, message transfer to each subsequent node is moved in an algorithmic order. Additionally, this may be automated with suitable algorithms. Electric utilities benefit from the adoption of wireless mesh, particularly when processing output data. The transmission of WMN across mesh nodes, mesh clients, and gateways makes it possible to meet the demand to increase efficiency and services while also attracting more users to smart grid infrastructures. It is also crucial to establish connectivity between smart meters and data center by wireless mesh networks [157]. As beneficial as wireless mesh is for smart grid communication, installation timelines and operating costs might occasionally be long owing to highly optimized equipment used in the process or insufficient availability of such equipment in the intended usage locations [159].

3) CELLULAR NETWORK COMMUNICATION

Cellular refers to network distribution across an area, that are made up of transceivers cell. Cellular Network Communication (CNC), is similar to Zigbee and wireless mesh, is recognized as one of the communication technologies suited for smart grids and their applications. It includes, GSM, GPRS, and 3 G. High capacity, increased speed, meaningful data, and voice features are characteristics of CNC [159]. It also supports mobile cellular devices and includes a multimedia roaming option. Using them in smart grids is more than acceptable because they are the only method of communication for sensitive commercial dealings and mission critical services. CNC is the hub of communications that easily connects end-to-end wireless nodes [160].

4) WLAN

Computers and a number of other devices are frequently connected to the internet using the Wireless Local Area Network (WLAN) technology, which is considered to be industry standard [161]. Even though it is combined with ethernet technology, it is a modified form of that technology. It uses radio frequencies to broadcast and receive data quickly without connections. WLAN has a number of advantages for the smart grid [162]. Due to safety concerns, lack of availability, disruption, and data rates, WLAN has historically had a loose reputation in the energy industry. However, this is no longer the case, especially for smart grids [162], [163].

The following are few wired technologies that have been studied to take into account in the SSGs infrastructure.

5) POWER LINE COMMUNICATION (PLC)

PLC uses a line cable to communicate from device to device at high speed [164]. Due to the presence of existing lines, PLC technology is the only one whose setup cost can be comparable to that of wireless technology [165]. Due to its connections with the meter, it has been the most effective communication technique for electricity meters [166].

6) DIGITAL SUBSCRIBER LINES (DSL)

The subscriber lines for digital DSL is a technology that transmits digital data quickly over the voice telephone network. The fundamental features of DSL that help to keep installation costs down. This explains why so many businesses choose DSL technology for smart installation. This technology has been incorporated into several active international projects as a smart grid solution [167]. It makes use of a communication box that is installed on the site of the energy user, and data about the pattern of usage of energy is sent to the utility company that employs the technology through DSL [164].

7) FIBER OPTIC

Fiber optics play a crucial role in information transfer that cannot be overstressed. The telecommunications framework has changed as a result of the novelty surrounding the usage of this material. In order to prevent interference and signal noise when transporting data from one location to another, this technology employs light waves instead of electricity [168]. The enormous volume of data that can be transmitted across a very long distance of more than one hundred kilometers in a relatively little period of time is another benefit of this wired media. With a layer of plastic cover that guards against damp, installation is simple. Fiber optics are available in many multimode and single mode configurations. Although they are employed in communication networks as well as in medicine and surgery, they also play a significant part in the smart grid, just as coaxial and twisted pair cables, which are members of the same wired communication group [169].

8) SCADA

Remote control of industrial operations is made possible by SCADA, which consists of hardware and software components. SCADA has recently been used for energy management, such as smart grids [170]. The advantages of SCADA include its ability to evaluate real time data and communicate directly with equipment like pumps, sensors, and

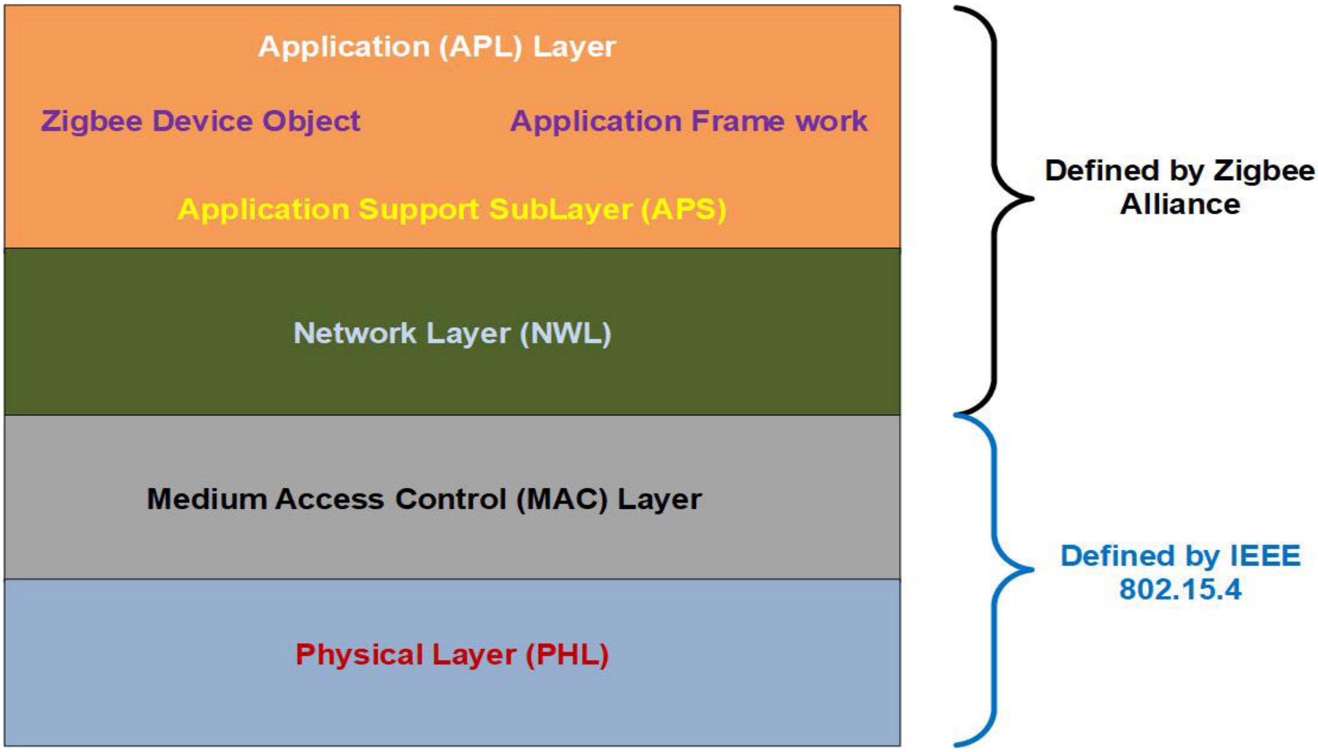


FIGURE 31. Layers of Zigbee.

motors [171]. The Human Machine Interface (HMI) software is used to perform this. Additionally, Supervisory Computers, Remote Terminal Units, Programmable Logic Controllers, Communication Infrastructure, etc. are frequently utilized in SCADA systems. Fig. (32) depicts the fundamental architecture of a SCADA system. Additionally, it maintains event logs, boosts productivity, and reduces downtime. SCADA architecture, common operational protocols, data transfer technologies, and graphical user interfaces all improve the high level supervisory process. While challenged with cyber-security difficulties that are now being controlled utilizing contemporary security solutions, a number of businesses, particularly the power industry with big SCADA systems, have evolved to become resourceful in vast distance site monitoring [172].

The Fig. (33) shows the various categories of wireline and wireless communication on SSGs [173].

M. MODELLING AND INCORPORATION OF RENEWABLE ENERGY SOURCES IN SSGs

When an approximate mathematical model is given, it is simpler to verify the system compatibility before manufacturing without spending any money. The modeling method aids in decision making by enabling the identification and enhanced understanding of component features. Although accurate performance prediction is reflected in detail modeling, designing the ideal model is either too difficult or takes too much time. A good model should be matched between complexity and reliability.

The next step after creating a mathematical model is to deploy a computer simulation model to test the system outputs under various input scenarios and to check for stability. Before creating the final working model, these computer simulations may be used for additional analysis, to replace specific components, or to reconsider the system and optimize it [174]. The mathematical modelling of the system is also required to design appropriate controller for any proposed system. The performance of each dynamic state in model can be evaluated by designed controller [175].

1) MATHEMATICAL MODELLING OF WIND TURBINE

In this review paper, we have considered the wind turbine as a renewable energy source linked with clusters. The Fig. (34) illustrates the fundamental parts of conventional wind turbine generator [176]. To design a robust nonlinear controller for MMPT of wind turbine a mathematical dynamical equations should be required to track the maximum power from the wind to fulfill the requirement of the clusters through SSN and designed energy management algorithm. This techniques can be implemented for SSGs having multiple cluster comprises of wind turbine. The formulation of mathematical modelling of wind turbine can be follow as;

Considering “K.E” is the kinetic energy of an object having mass and velocity “M” and “V” respectively, a constant acceleration “A” produced an object due to applied force

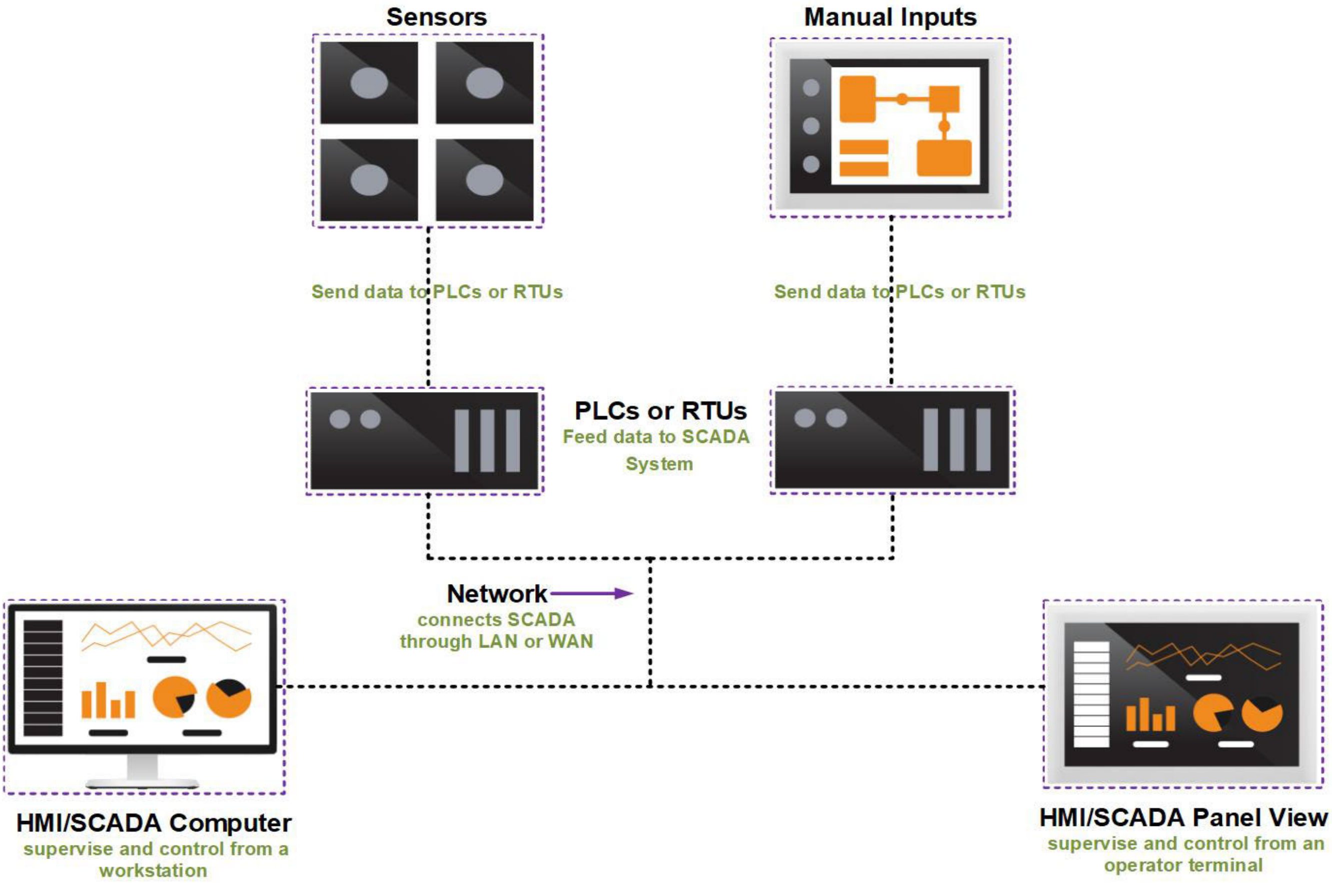


FIGURE 32. Main components of SCADA system.

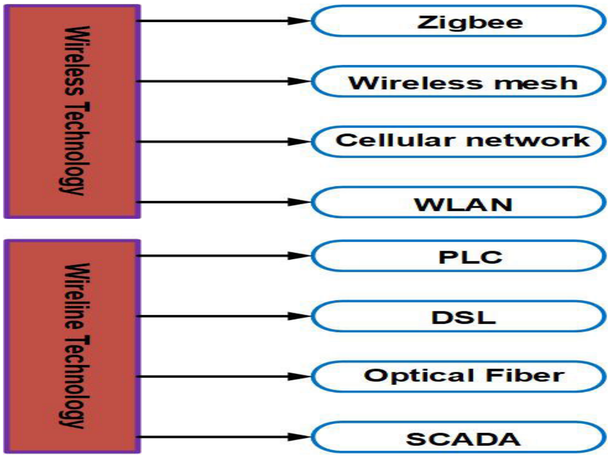


FIGURE 33. Wire and wireless communication categories.

which covers some displacement "D", so, the work "W" done on the body is;

$$W = F.D \tag{62}$$

The work is also equal to change in energy therefore,

$$k.E = F.D \tag{63}$$

Now according to the Newton second law of motion;

$$F = MA \tag{64}$$

Putting the value of eq. (64) in eq. (63) we get;

$$K.E = MAD \tag{65}$$

The third equation of motion is given as;

$$u_f^2 = u_i^2 + 2AD \tag{66}$$

From eq. (66) the value of 'A' can be obtained as;

$$A = \frac{u_f^2 - u_i^2}{2D} \tag{67}$$

where u_f and u_i are the final and initial velocity of an object.

Putting the value of 'A' from eq. (67) into eq. (65) by assuming $u_i = 0$ and $u_f = V$;

$$K.E = \frac{1}{2}MV^2 \tag{68}$$

The assumption behind this kinetic energy eq. (68) is that the mass is constant. But for considering wind (moving air) like a fluid with variable density and velocity, having no fixed mass. Because of this, the kinetic energy law is expressed with a

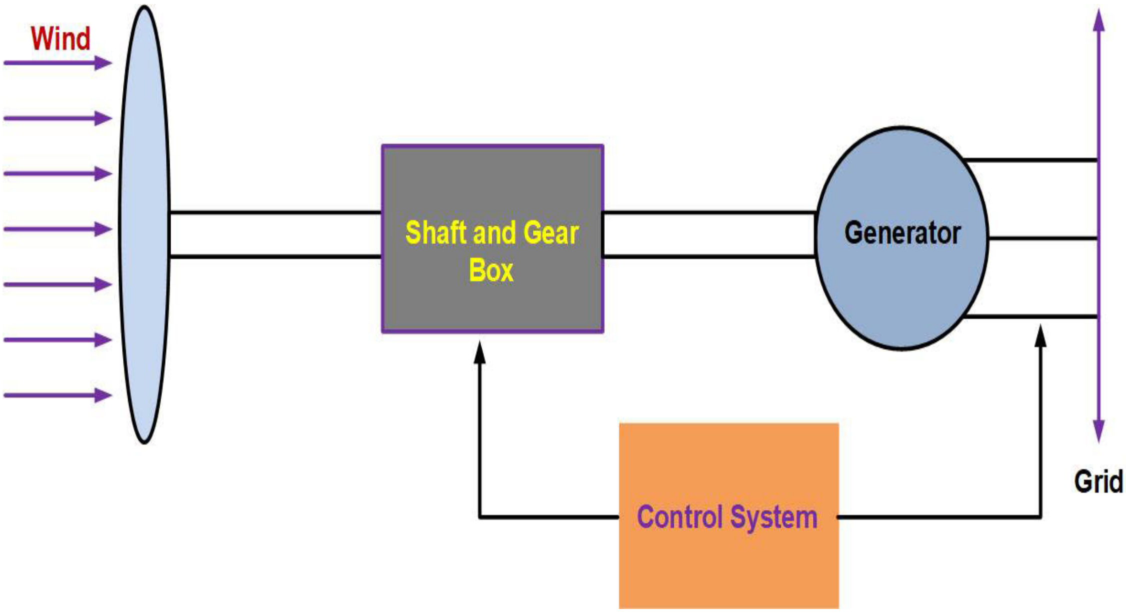


FIGURE 34. Major blocks in wind turbine.

factor of 2/3 rather than 1/2 [177]. The power 'P' of wind is equal to the derivative of K.E with respect to time, therefore;

$$P = \frac{dK.E}{dt} M V_a = \frac{1}{2}\frac{dM}{dt} V_a^2 \tag{69}$$

where V_a is the velocity of wind and $\frac{dM}{dt}$ is the flow rate of mass which is equal to;

$$\frac{dM}{dt} = \rho S V_a \tag{70}$$

where $'\rho'$ and 'S' are the density of wind and area in which air is flowing respectively.

Using the value of eq. (70) in eq. (69) to get;

$$P = \frac{1}{2}\rho S V_a^3 \tag{71}$$

The real power P_r of the wind is obtained from the blades of the rotor is equal to the difference between upstream and downstream power of the wind turbine [178].

$$P_r = \frac{1}{2}\rho S V_a (V_f^2 - V_i^2) \tag{72}$$

where V_f and V_i are the upstream velocity of the wind at which enter the rotor blade and downstream velocity of wind at the outer end of rotor blade respectively.

Now from eq. (70) the mass flow rate can be written as;

$$\rho S V_a = \frac{\rho S (V_f + V_i)}{2} \tag{73}$$

where V_a is the average of in and out velocities of the rotor blade in wind turbine, therefore, eq. (72) can be expressed as;

$$P_r = \frac{1}{2}\rho S (V_f^2 - V_i^2)\frac{V_f + V_i}{2} \tag{74}$$

The eq. (74) can be simplified as;

$$P_r = \frac{1}{2}\left[\rho S\left(\frac{V_f}{2}(V_f^2 - V_i^2) + \frac{V_i}{2}(V_f^2 - V_i^2)\right)\right] \tag{75}$$

$$P_r = \frac{1}{2}\left[\rho S\left(\frac{V_f^3}{2} - \frac{V_f V_i^2}{2} + \frac{V_f^2 V_i}{2} - \frac{V_i^3}{2}\right)\right] \tag{76}$$

$$P_r = \frac{1}{2}\left[\rho S V_f^3\left(\frac{1 - (\frac{V_i}{V_f})^2 + (\frac{V_i}{V_f}) - (\frac{V_i}{V_f})^3}{2}\right)\right] \tag{77}$$

or

$$P_r = \frac{1}{2}\rho S V_f^3 W_h \tag{78}$$

where

$$W_h = \frac{1 - (\frac{V_i}{V_f})^2 + (\frac{V_i}{V_f}) - (\frac{V_i}{V_f})^3}{2}$$

or

$$W_h = \frac{(1 + \frac{V_i}{V_f})(1 - (\frac{V_i}{V_f})^2)}{2} \tag{79}$$

where W_h is known as Betz limit, which is the ratio of upstream power of the wind taken from the rotor blade of turbine.

However, the ratio downstream velocity to upstream velocity of wind turbine is denoted by C;

$$C = \frac{V_i}{V_f} \tag{80}$$

or

$$C = \frac{speed\ of\ blade}{speed\ of\ wind} \tag{81}$$

The value of speed of blade can be calculated from eq. (82) as;

$$speed\ of\ blade = \frac{rotational\ speed\ of\ turbine \times R}{speed\ of\ wind} \tag{82}$$

where R is the radius of turbine and rotational speed can be measured in $radian/sec$.

Now put the value of eq. (80) in eq. (79) to yield;

$$W_h = \frac{(1+C)(1-C^2)}{2} \tag{83}$$

Most of the wind will flow through the gaps between the blades of a wind turbine if the rotor rotates too slowly, generating little electricity. In contrast, if the rotor spins too quickly, the rotor blades operate as a solid barrier, preventing the wind flow and lowering the amount of power that can be extracted. In order to get the most power out of the wind flow, the turbines must be built to run at their ideal wind tip speed ratio. Greater the value of C the performance of the generator will be better. But there are drawbacks as well. Due to the contact of sand or dust grains in the air, high causes deterioration of the blades leading edges. This would imply the use of a specific coating material that is resistant to erosion, which might raise the cost of electricity. In addition to producing noise and vibration, higher decreases rotor efficiency owing to drag and tip losses, and too-high rotor speeds can result in turbine failure [179].

The infrastructure of super smart grid system comprises various RERS. It can link generators that are radially connected to the grid [180]. SSGs is adaptable enough to operate dispersed generation systems and can even control voltage for deeply integrated RES [181]. Frequency regulated and responsive loads are added to the smart grid in order to increase reliability. High levels of integration of small and medium sized renewable energy generating units give rise to a number of problems, including synchronization between sources and generally with the grid, the reduction of harmonics to prevent distortion, and the smoothing of voltage variation [182]. The operation of optimization in super smart grid, that enables end users to effectively regulate energy usage and prevents power outages. Due to distributed power generation and storage, the smart grid has opened up a wide range of opportunities. This energy can be dynamically contributed to the system at different levels, such as the transmission and distribution sector [183]. With the aid of significant developments in communication, computation, and sensor networks, the issues of disturbance and power transfer can be resolved. The basic model of a single cluster smart grid is shown in Figure (35). Optimization tools is used to check and balance the requirements of the power between demand and supply sides along with optimization of other parameters.

To resolve the energy storage issue has frequently grown as a result of the practical uses of renewable energy sources. Electric vehicles may store energy from the smart grid system to become charge in G2V mode [184]. The Linkage of PEVs and PHEVs with RERs provide a numerous advantages including improving the environment, lowering vehicle operating costs, consuming less fossil fuel, and emitting fewer dangerous gases [185]. Fig. (36) shows the control and manage of power for smart home management system [186]. The power from the renewable energy resources can be directly supplied to the grid. The battery can be charged from the grid when the requirement of the loads is low and discharged when the demands of the load is high.

The combination of a large number of PHEVs act as a loads on the grid might lead to a number of issues, including voltage stability and overloading of transformers or lines [127]. Many approaches have been proposed to solve these problems in PHEVs [187]. Two types bidirectional converters required for smooth operation of G2V and V2G modes. The first converter operate as a boost rectifier while other convert act as a buck converter that directly connected to the battery of electric vehicle in G2V Mode. In V2G modes the operation of these converters become reverse. The working principle of these converters based on constant current-constant voltage (CC-CV) topology. The mathematical modelling of both converters have been derived in [188].

Batteries from PHEVs serve as distributed energy resources in a V2G system by directly fulfilling demand during peak times, which relieves stress on overburdened distribution networks. The aggregator, which a communication link is utilized for interaction between vehicle owners and distribution network service providers (DNSPs), estimates the quantity of electricity transferred by vehicles to the grid [189]. When batteries employed in V2G systems suddenly run out, the distribution networks to which they are attached may experience voltage variations, which in turn results in voltage stability issues. Additionally, power electronic converters serve as interfaces between the grid and the batteries of plug-in hybrid electric vehicles (PHEVs), therefore a reliable switching system is necessary to preserve the power quality and stability. A powerful controller has to be needed that can reduce the voltage fluctuation problem through reactive power management and improve the power quality of distribution networks in V2G system [190].

2) MODELLING OF V2G SYSTEM

In order to ensure the steady performance of such systems with excellent power quality, designing of linear and nonlinear controllers relying on the mathematical model of V2G systems would be essential. The Fig. (37) illustrates the interaction between grid and vehicle during G2V (Charging) and V2G (discharging) modes with the help of interfacing medium such as power converters [191].

The modelling of a V2G system is proposed in this section of the paper.However, a battery model is analyzed before developing the primary V2G system as this is a key component of a V2G system. The Fig. (38) depicts the model of the battery that mostly used in V2G system;

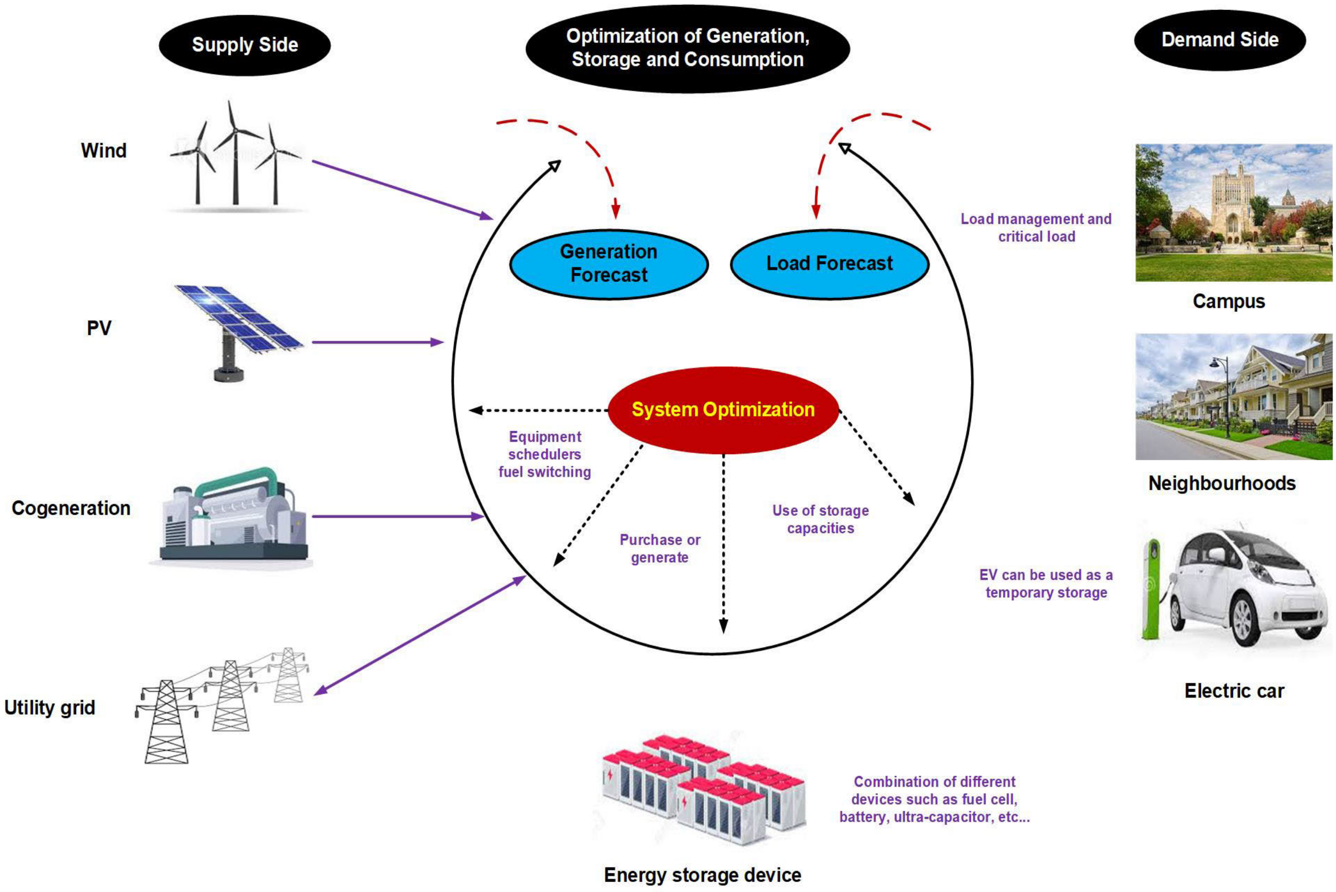


FIGURE 35. Infrastructure of single cluster in SSGs.

The electric circuit of the battery includes three resistors R_0, R_1, R_2, one capacitor C_1 and internal voltage source E_m [192]. The Fig. (39) shows the V2G system with battery model.

Now after applying KCL law in Fig. (39), we have;

$$I_s = I_c = I_{R_1} + C_1 \frac{dV_{C_1}}{dt} \tag{84}$$

where V_{C_1} represent the voltage across capacitor C_1, the capacitor C_1 and resistor R_1 are parallel with each other therefore,

$$V_{C_1} = I_{R_1} R_1 \tag{85}$$

Using the value of eq. (85) in eq. (84) to get;

$$\frac{dI_{R_1}}{dt} = \frac{1}{\lambda}(I_c - I_{R_1}) \tag{86}$$

where

$$\lambda = R_{1C1}$$

After applying KVL on the grid side of Figure (V2G system) we get;

$$\frac{dI_g}{dt} = -\frac{R_L}{L_L} + \delta \frac{V_c}{L_g} \tag{87}$$

where δ is the duty ratio of the converter that depends on the modulation index and firing angle, while R_L and L_L represent the resistance and inductance of the line respectively.

The eqs. (86) and (87) show the model of V2G system in time variant domain. For designing the controller for V2G system the model must be converted into time invariant model that can be represented on dq frame [190], therefore;

$$\dot{I_{R_1}} = \frac{1}{\lambda}(\delta_d I_d + \delta_q I_q - I_{R_1}) \tag{88}$$

$$\dot{I_d} = -\frac{R_L}{L_L} I_d + \omega I_q - \frac{E_d}{L_L} + \frac{V_C}{L_L}\delta_d \tag{89}$$

$$\dot{I_q} = -\frac{R_L}{L_L} I_q - \omega I_d - \frac{E_q}{L_L} + \frac{V_C}{L_L}\delta_q \tag{90}$$

where ω represents the angular frequency. The δ_d and δ_q show the duty ratio of converter in d and q frame respectively. The E_d and E_q are the grid input voltage in d and q references respectively.

The active and reactive powers injected from vehicle to grid in dq frame can be given as;

$$P_{V2G} = E_q I_q + E_d I_d \tag{91}$$

$$Q_{V2G} = E_q I_d - E_d I_q \tag{92}$$

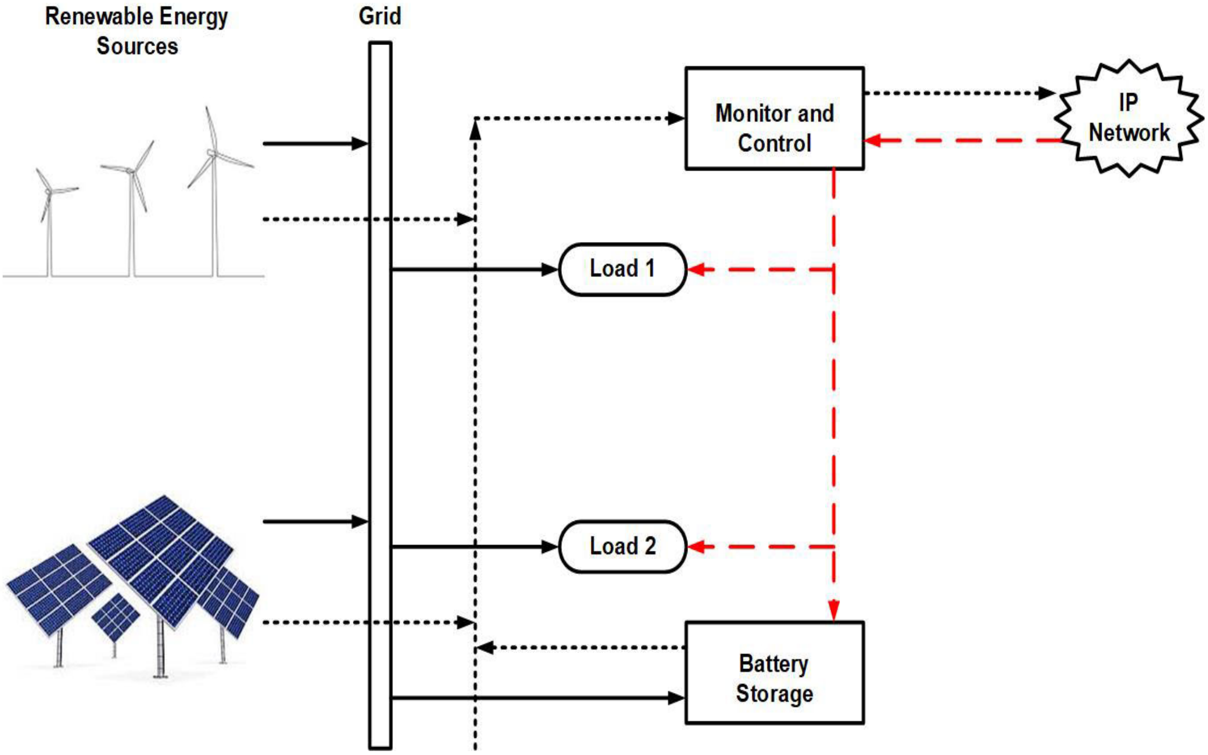


FIGURE 36. Monitoring and control system for smart home.

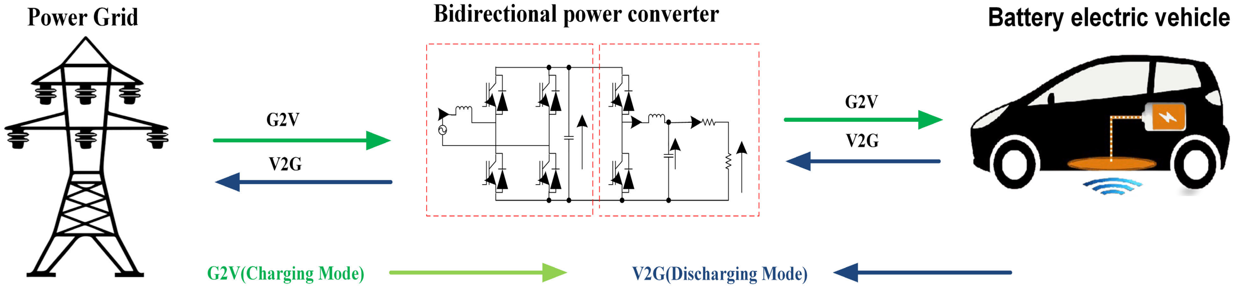


FIGURE 37. Directions of power in G2V and V2G mode.

The eqs. (91) and (92) show the active and reactive from the vehicle to grid respectively.

In dq reference frame the value of $E_d = 0$ [193], therefore eqs. (91) and (92) becomes;

$$P_{V2G} = E_q I_q \tag{93}$$

$$Q_{V2G} = E_q I_d \tag{94}$$

The eqs. (88), (89) and (90) represent the complete dynamic model of V2G system. However the quality of power depends on the current as expressed in eqs. (10) and (11). Therefore a robust controller must be required to transfer the energy from vehicle to grid after TPF occurred in any cluster of the SSGs. The V2G technology is the possible way that fulfill the requirement of the load which is the main advantage of this topology while controlling of power flow is a challenging task in super grid by introducing V2G technology [194]. The non linear controller to be needed for smooth operation of power converters in G2V and V2G modes. The regulation of voltage can be done through a boost converter while correction of power factor has performed by buck boost converter connected to the battery of electric vehicle [195], [196].

XI. CONTROL STRATEGIES OF SUPER GRID

The control challenge is extremely difficult since it demands for achieving reliability, efficiency, and outstanding performance. The control designer are also responsible for the process modeling, simulation, and diagnosis of parameters [197]. The usage of PID controllers has decreased as a result of safer operating guidelines and the need for extra compensators to ensure PID controller functionality [198].

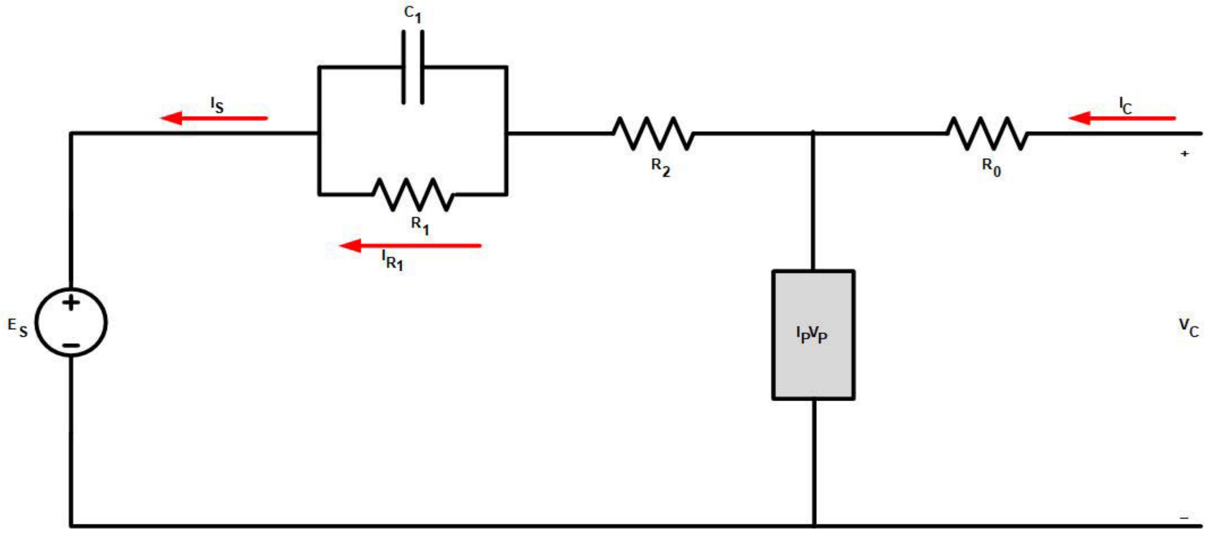


FIGURE 38. Battery model in V2G system.

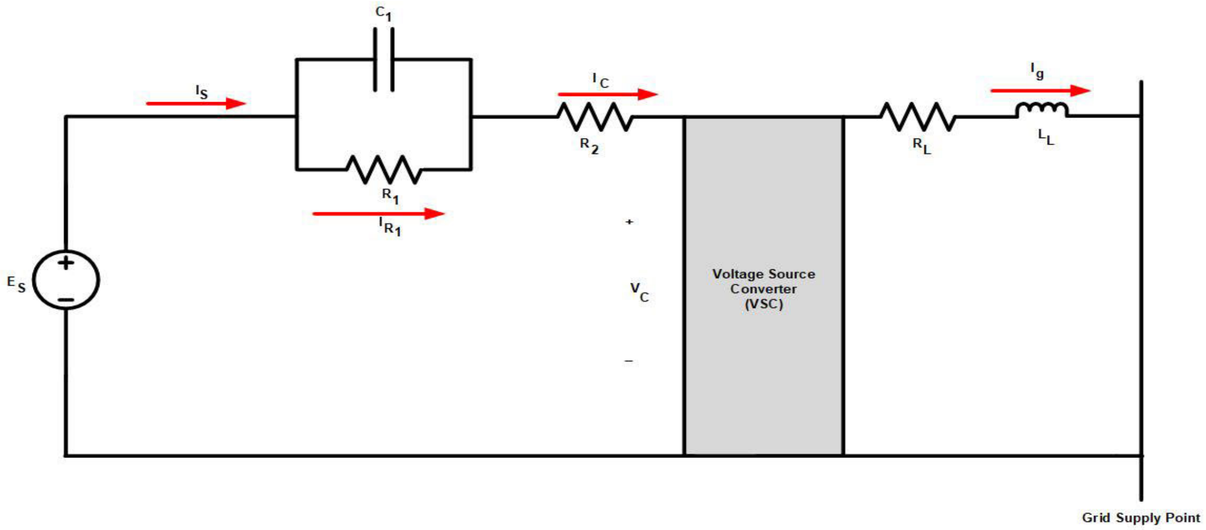


FIGURE 39. Circuit diagram of V2G System.

In addition, PID experiences integrator windup problems, which worsen disturbance responses when the actuators are saturated. An antiwindup control strategy is typically used to address this problem, as seen in Fig. (40).

For PID based control methods that reduce the impact of measurable disturbances, a feed forward controller is also essential [199]. The sensed disturbances are utilized to identify the controlled variable based on a defined model in order to maintain the control at the reference point. Errors in modeling are compensated by the feedback [200]. The implementation of the technique is possible in serial or parallel arrangement. the serial arrangement is shown in Fig. (41).

For regulating the grid system filtering process, inverting process, DC link, and controlling grid side parameters, a LQR based control has been implemented in [201]. In the cascade control approach, the inner loop is used to regulate disturbances, while the outer loop is used to control the output of the process. A cascade control block diagram is shown in Fig. (42). A primary controller regulates the collector region by using secondary controller. The Distributed Control System (DCS) mode having cascading control of a solar array is used for regulating average temperature and combining oil demands that discussed in [202] and [203].

As seen in Fig. (43), Adaptive Stochastic Control (ASC) may optimize the sources and loads that are part of smart grids. These technologies can recognize the worst case events that might occur in the plants [204]. The control center based on adaptive system that linked with generation and consumption unit. The different line transformers are also used in transmission network according to the requirements of the load.

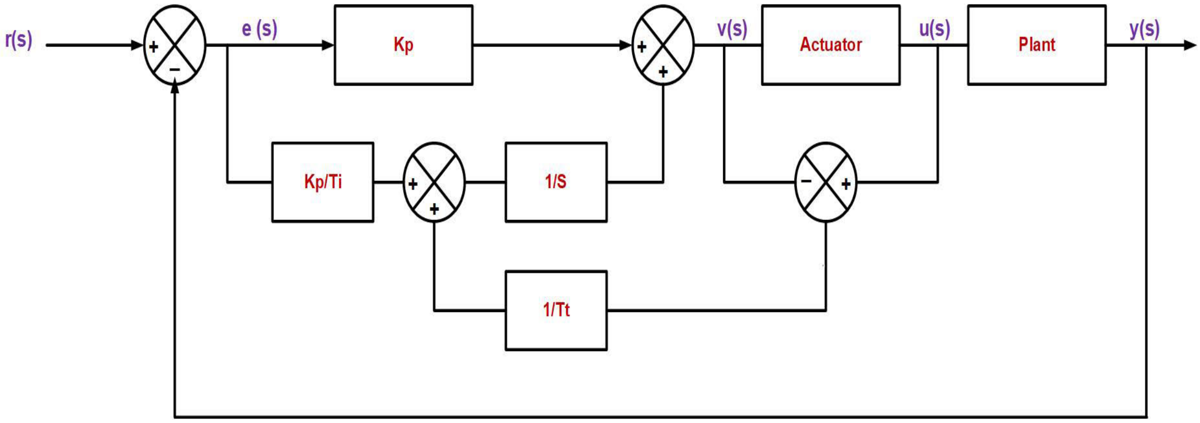


FIGURE 40. The antiwind setup with PID controller.

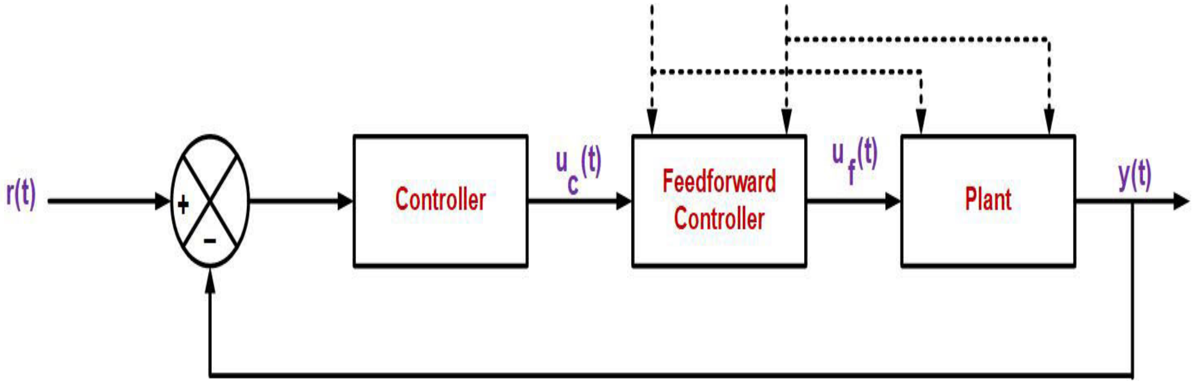


FIGURE 41. Series configuration of the controller.

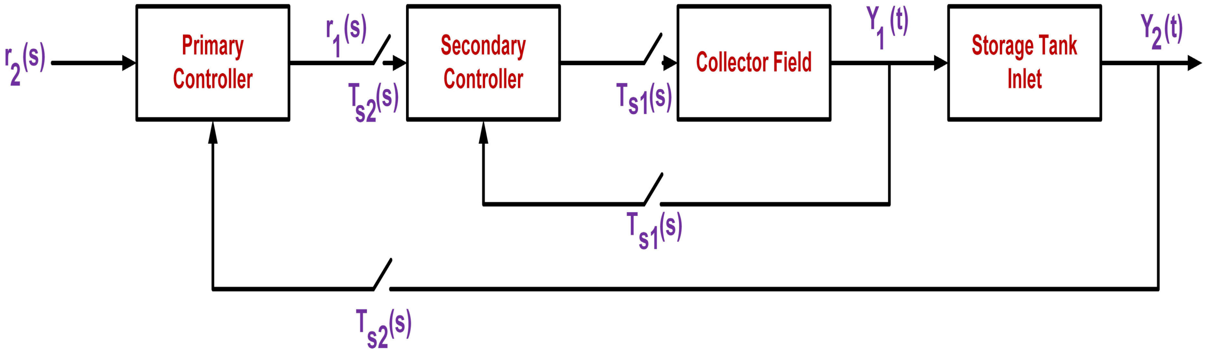


FIGURE 42. Cascaded control mechanism.

Volt-VAR Control (VVC) is also widely used to maintain the operating requirements for the distribution system of the smart grid. The main goal of VVC is to achieve appropriate voltage levels at all distribution system locations while taking into account all loading conditions. Due to "self healing," this control strategy improves efficiency while maintaining voltage level. It uses standalone, On Site Voltage Regulator (OVR), rule based DA control, heuristic voltage regulation, and distribution based model VVC [205]. AGC (Automatic Generation Control) guarantees the frequency and power setting schedule stability of the smart grid. The AGC technique reduces the load forecasting ambiguities and failures [206]. Autonomous Plug in Electric Vehicles (PEVs) employ optimum charging control algorithms. There are two different types of PEV coordinating strategies: distributed and decentralized. The interaction and utilization of PEVs in grid level carried out in [207].

The delay and phasor qualities prevalent in smart grid systems are corrected by the Adaptive Power Damping Controllers. Power System Stabilizers (PSS) and FACTS controllers are the two different types of Power System Electromechanical Mode Damping Controllers. A

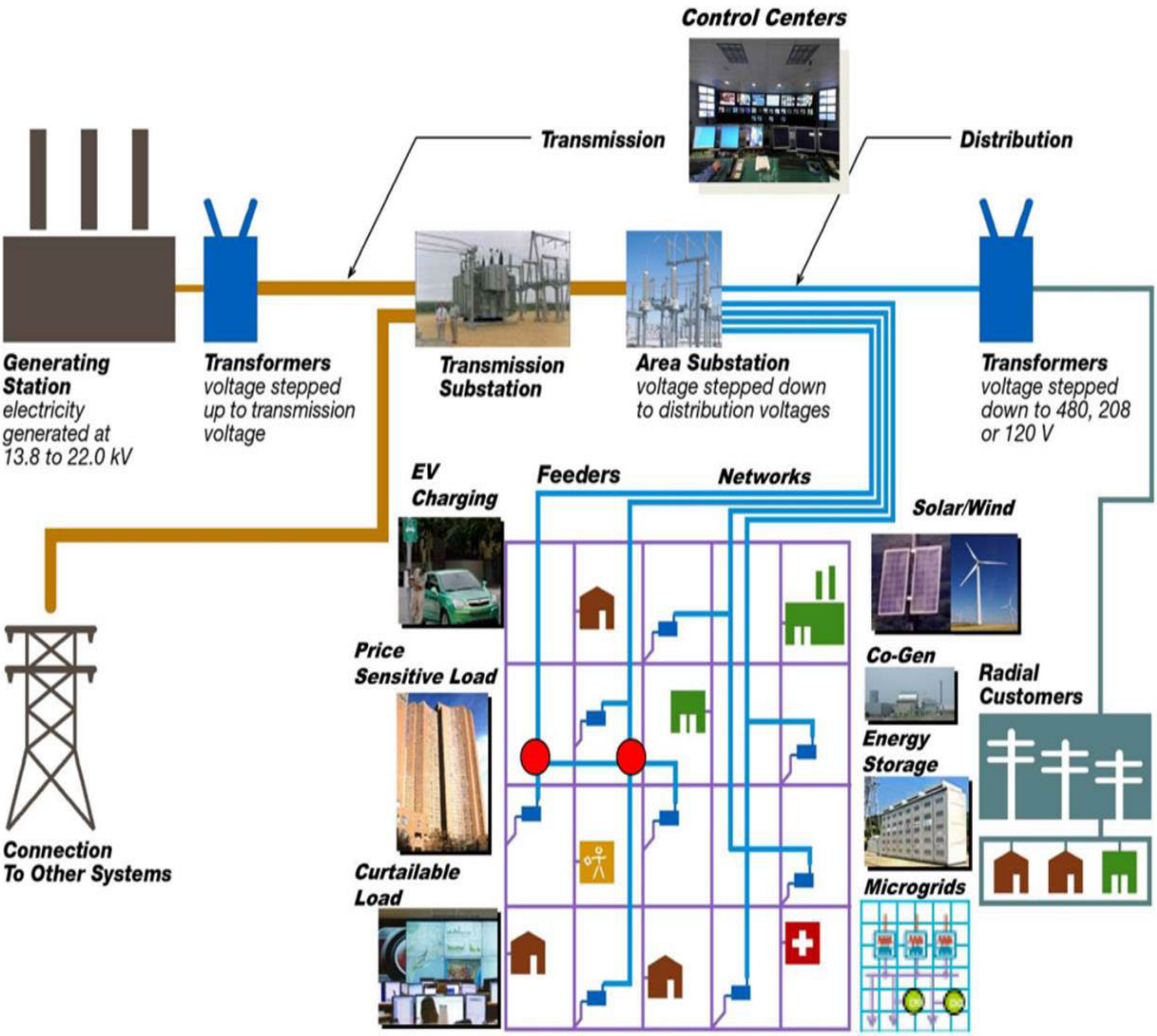


FIGURE 43. Block diagram of adaptive control for grid system.

number of Phasor Measurement Units (PMU) for damping control are presented in [208]. The block diagram for the Adaptive Power Damping Controller is depicted in Fig. (44).

The Model Reference Control (MRC) technique is used to make sure the smart grid system is reliable and long lasting. Model reduction, Collective Control, and Control the process of inversion are the three phases of the MRC technique suggested in [209].

The flow of energy in solar systems, smart grids, storage devices, and consumer loads is managed by adaptive logic controllers (ALC). The balanced power flow and the effects of the weather are also taken into consideration. ALC can create its own controlling and optimizing algorithms for issues like energy demands, pricing signals, the availability of resources, loading schedules, etc. [210]. ALC block diagram is shown in Fig. (45).

Several other approaches have been studied for the control and management of super smart grid which are discussed in below sections;

A. ROLES OF OPTIMIZATION AND ARTIFICIAL INTELLIGENCE IN SUPER GRID

The optimization tool is proposed to optimize the cost of different parameters, while Artificial Intelligence (AI) used for prediction of output based on previous data.

1) OPTIMIZATION TECHNIQUES

The term super smart grid refers to a complex system, and the components of a smart grid are classified according to a set of standards, including homogeneous parts, interconnected elements, and characteristics of general interest. For a residential area with low requirements of power consumption,

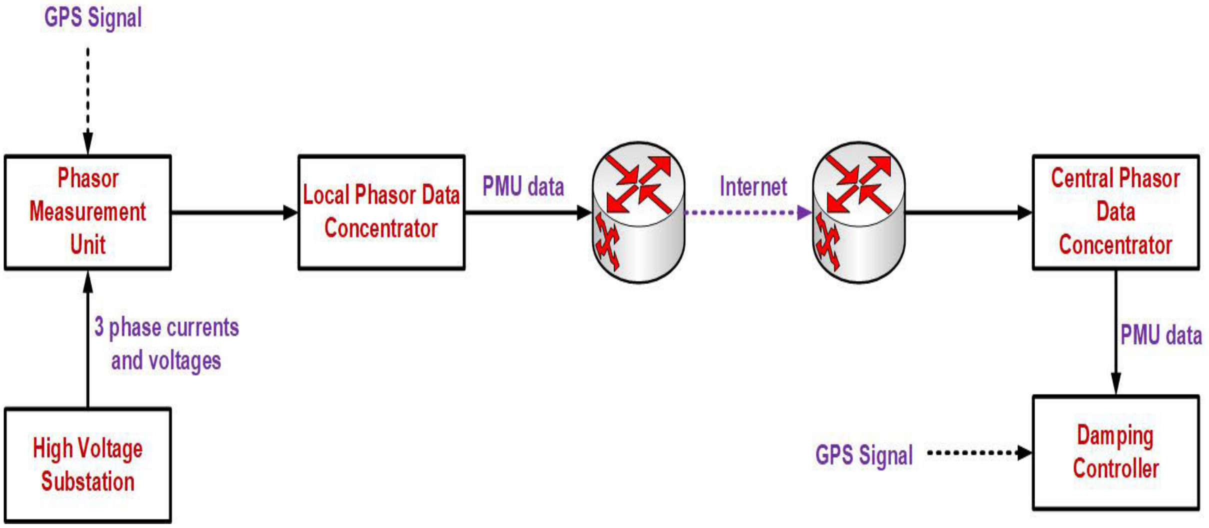


FIGURE 44. Damping controller for power.

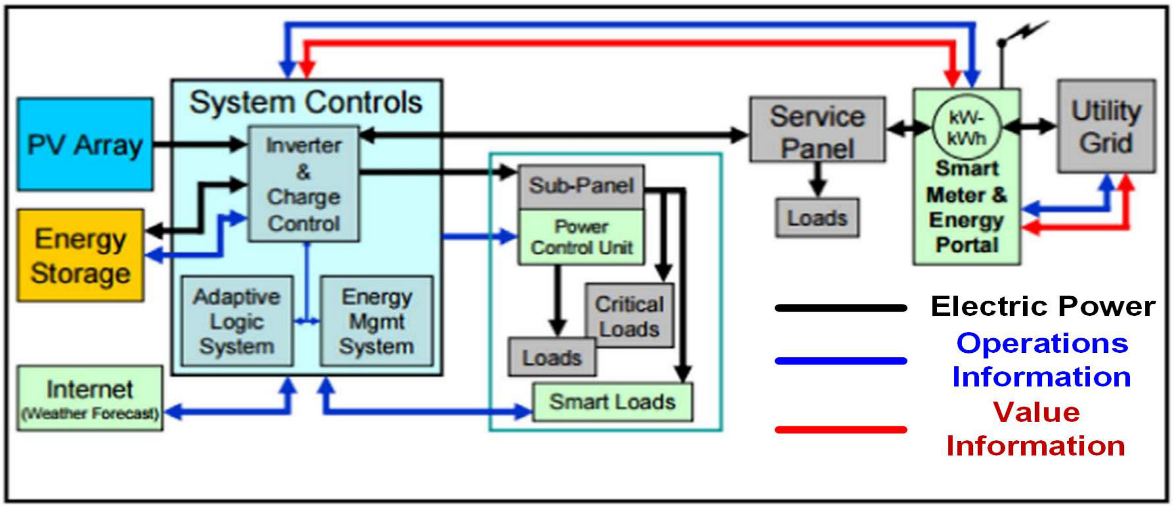


FIGURE 45. Adaptive logic controller for control and operation of power in smart grid system.

a single optimization technique may be used. Optimization of a super smart grid system is a tough task due to its complex infrastructure. Typically, the classical and game theoretical approaches are used to optimize and guarantee the flexibility and sustainability of the grid [211].

The grey wolf optimization (GWO) technique has been proposed for the super grid of Iran having 400V voltage. The purpose of designed GWO to control the flow of power and reducing the losses in transmission lines along with other parameters. It's been proved that the proposed GWO shows better performance against other optimization techniques in term of cost minimization, power losses and voltage stability index (VSI) [212]. The distributed generation methods for improvement of Iraq's 400kV gid system has been discussed in [213]. A GwO technique has been proposed for the improvement of voltage profile in power system infrastructure [214].

The major problem in super grid is the flow of optimal power by designing a novel hybrid technique based on particle swarm optimization (PSO) algorithm and salp swarm optimization (SSO) algorithm. This technique is proposed for solving the optimal power flow problem which deals with non linear optimization problem in electric power system. It solved different designed objective functions such as cost, power losses and enhancement in voltage [215]. The selection of features plays main role in the field of AI which is based on availability of data to increase the performances, therefore this problem has been reviewed in [216] by designing GWO technique. A improved Differential Evolution algorithm (IDEA) has been proposed to optimize the flow of power. The effectiveness of proposed technique has been tested by solving different objective functions under standard IEEE 57 bus system and IEEE 30 bus system for the applicability and uses in real life scenario [217]. The linear programming (LP) and the sequential quadratic programming (SQP) tools have used that available in matlab environment to control the reactive optimal power flow and decreases the energy losses to make the voltage profile effective [218].

To determine the location for installation of PV system using GWO algorithm to optimize the losses caused by active power has studied in [219]. The Solar microgrid along with hybrid energy storage system (HESS) has been proposed to increase the storage of energy and it plays basic role in super grid infrastructure [220]. The integration of pV system with smart grid have been examined and the researcher proposed the line conditioner to extract the maximum power point tracking (MPPT) of PV system, for this purpose neuro fuzzy controller has been designed in [221].

A modified African Buffalo Optimization (MABO) has designed to control the two stage frequency among interconnecting many microgrid. It's performance has been checked by varying different parameters such as variation in voltage and disturbance on load. The enhancement and stability of grid has been proved by connecting electric vehicle to the grid [222]. The effect of electric vehicle in term of pros and cons on grid under various circumstances have been recorded in [223]. The different factors such as feasibility and cost of standalone and hybrid grid connected system have been analysed. The Particle Swarm Optimization (PSO) and Exchange Market Algorithm (EMA) have been proposed to mitigate the power losses and optimize the size along with better locations in [224]. The multi objective predictive energy management algorithm has been proposed for the HESS of residential grid connected system. The designed algorithm is based on theroy of machine learning [225]. The Swine Influenza Model Based Optimization with Quarantine (SIMBO-Q) has been suggested to minimize the total cost of operations of grid along with battery storage system. The suggested algorithm based of probability of quarantine and treatment loop. This technology can be useful to optimize the total cost of super grid infrastructure [226].

Shunt VARs Compensators (SVCs) and Thyristor Controlled Series Compensators (TCSCs) have been suggested instead of Flexible AC Transmission Systems (FACTS) device due to its high cost. Particle Swarm Optimization (PSO) has been considered to optimize the location and size of device for stability and flexibility of grid [227]. A computational methods has employed to analyse the supply and demand response in distributed network (DR). Its proved that the quantum algorithms shows better performance in DR among overall computational methods [228]. The Fig. (46) represents the categories of analysis of power system along with classification of probabilistic technique, which may be useful for long transmission in super grid to minimize the cost along with other necessary factors.

The different approaches have been discussed to analyze the modeling of super grid infrastructure. The modeling with uncertainty would be the better choice as compared to deterministic due to external perturbation and renewable energy resources in super grid system. However, it's also important for the management of energy system in grid infrastructure [229]. Furthermore, the uncertainty modeling can be done through possibilistic, probabilistic, optimization and analysis of interval.

2) ARTIFICIAL INTELLIGENCE

The artificial intelligence plays a major role in super grid infrastructure, for the communication purpose between various clusters. Different artificial intelligence techniques have been proposed for renewable energy and smart grids [230]. The fault detection in smart grid can be detected by using concept of AI. The application of AI in smart grid has been noted and reviewed the control mechanism for smart grid using AI approach. The shunt hybrid filters (SHF) has suggested for enhancement of power quality in smart grid [231]. Adaptive Fuzzy Neural Network (AFNN) has employed to cater the various objectives in smart grid system at different load conditions [232]. Artificial neural networks based on machine learning has proposed solutions for many wireless communication problem in lights of pron and cons [233]. The self building and self learning of AI based on machine learning has been explored and mentioned the advantages and disadvantages of self learning algorithm along its application in smart cities [234].

The concept of super grid and super block concept have been suggested for china cities. Super grid consists of a number of cell called super block. The researchers explored the modern structure and future advancement in super block connectivity for application in smart cities [235]. The effect of AI in practical life has been studied that how the life affected by AI when coming in real world. The huge amount of data has been collected from smart cities by employing machine learning algorithms. It's labeled the wasted data and proposed the three level strategy to convert these wasted data into efficient data [236], [237]. The deep learning algorithms has been implemented for detection of wrong way driving. The detection of way can be automatically detected by rotating the camera, to reduces the chances of accident [238]. The different approach of machine learning have been proposed, to handle the problems related to energy management strategy by introducing electric vehicles charging system in smart cities [239].

The different research area of AI have been mentioned such as power equipment based on AI algorithm, management of power and Image recognition technology. The AI is combined with big data and IoT to improve the performance of power system [240]. The different applications of AI has been discussed such as production of power along with distribution and transmission, energy saving methods having proper policy to controls its consumption. The scholars also mentioned the proper way of communication for

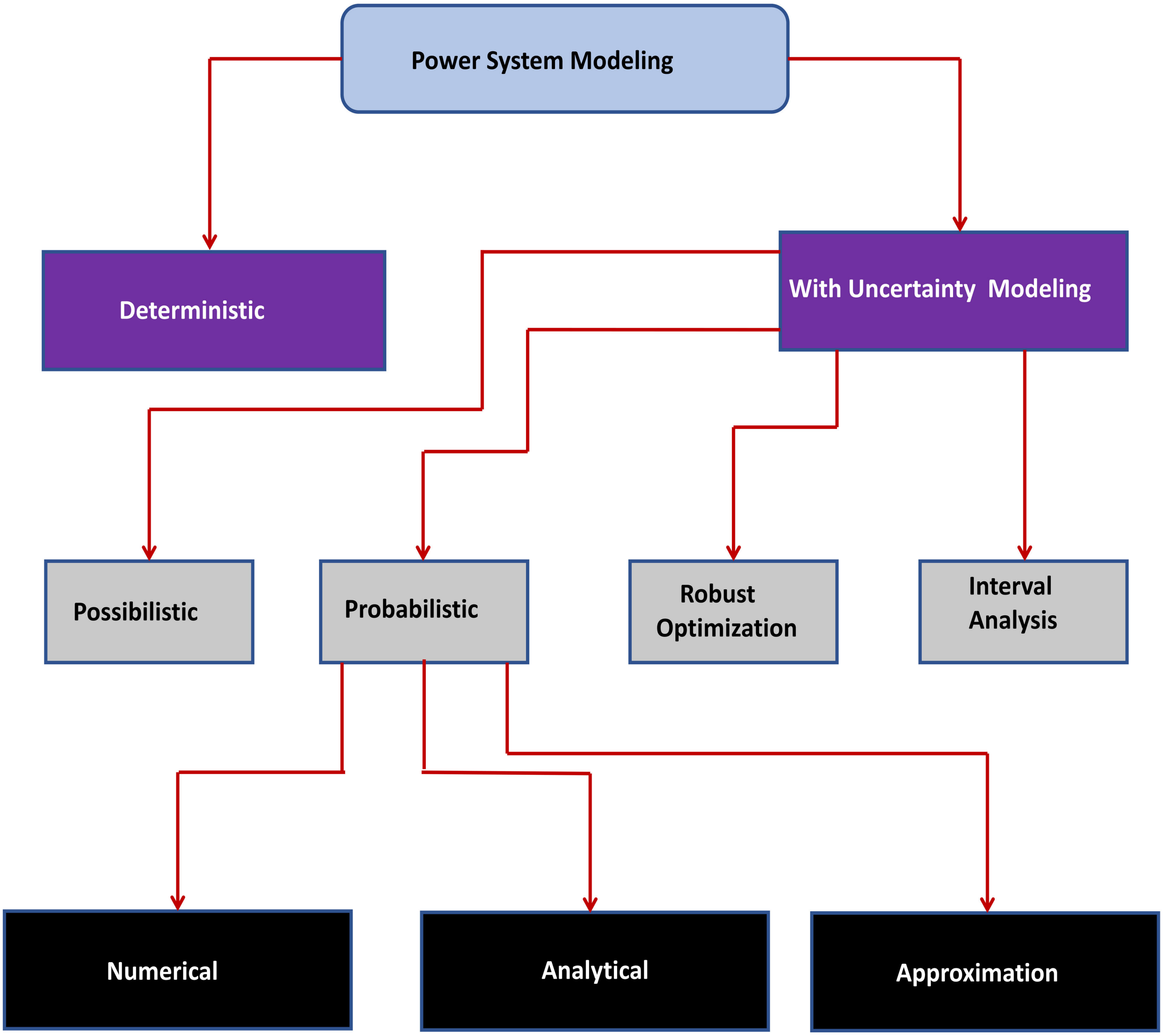


FIGURE 46. Power system analysis based on data.

input output data along with display of output [241]. The artificial neural networks has been suggested to evaluate the heat required for non residential building in European countries during winter season [242]. The AI technique has been proposed for better economics situation and job creativity in developing countries, this concept can be extended for communication between developed and developing countries in term of power system such as super grid system.

In India the emission of CO_2 has been predicted by employing ANN. its proved the better economic growth along with enhancement in energy sector [243]. The major role of AI has been highlighted in the field of business. The researchers show that how the business problem has been solved by implementing the concept of AI. It's expressed that the 50 different companies take help from AI domain [244]. The impact of AI and automation on different places and people have been studied in [245]. The application of AI in the filed of education specially tutoring and assessment have been explained in [246]. The relationship between AI and sustainable development have been studied in [247]. it's concluded that sustainable development is based on AI. The application of AI concept between online and offline application is presented in Fig. (47). It shows the AI operation on both cases online and offline. The online operation is based on online data that has taken from different IoT devices. The GPS has communicated with phasor measurement unit (PMU) to provide data to phasor data concentrator (PDC) in a wide area measurement system (WAMS). Real-time monitoring and control system checked the accuracy and type of data before providing to AI toolbox.

While the offline communication of AI evaluating the prediction that depend on training data which is further based on simulated and previous data of the system.

B. OTHER METHODS FOR PLANNING OF SSG SYSTEM

In this section we have reviewed a different typologies that could be used in infrastructure of super smart grid system.

The United State (U.S) Caribbean super grid has proposed to linked Caribbean island to power grid of U.S via High Voltage Direct Current (HVDC). it's considered the power profile as a tool for estimation of parameters and voltage that fulfill the requirement on both receiving and transmission sides [248]. The concept of both super grid and super block have been defined. It explored the connection from radial and grid to super grid and super block respectively [249]. The term global super grid is referred to the system in which overall electrical power is based on renewable energy. The researchers studied the operational and blockage factors that effects the global super grid [250]. A plan for implementing of super grid in 2023 has been discussed among five countries of Northeast Asia (NEA). The optimal network structure has been taken into account for Myerson (1977) value to shows the advantages of Myerson in SSGs [251]. The infrastructure of Australian grid has been linked with Asian grid named Australian–Asian (Power) Grid (AAG) by using super grid theory. It's also discussed the consequences of super grid in proposed AAG system [252]. The contribution of photovoltaic (PV) system in Association of Southeast Asian Nations (ASEAN) lead to the sustainable development by using SWOT method [253]. The transmission of solar energy from high concentration region to low concentration region in Turkey has been examined. The analysis of total cost for flow of energy has been calculated for HVDC transmission [254].

The Japan-Taiwan-Philippines HVDC transmission and its connection to Asian super grid along with technical challenges has been reviewed. The analytical framework has presented that how to become Australian grid system is a large exporter of renewable energy to the Asian grid. It's also considered the implementation of policy due to variable geopolitics situation of energy [255]. The analysis from 2015 to 2050 has been done for the transmission of renewable energy in Philippines. The linear optimisation tool has been proposed to consider variable renewable sources such as PV and batteries [256]. The comparison between HVDC and HVAC have been done and the components required for the HVDC has been discussed such as Voltage Source Converters (VSCs) and Line Commutated Converters (LCCs) [257]. The emerging of photovoltaic panel with grid has been explored in term of pros and cons. The scenario for power on both sides of supply and demand have been analysed [210]. The coordinated controller has suggested for the HVDC of the wind and battery energy storage system (BESS) to provide flexibility to the power system [258].

The conversion of HVDC system into multiterminal HVDC (MT-HVDC) grids has been explained with merging of renewable energy sources in MT-HVDc grids along with other challenging issues that have been discussed in [259]. The power coming from Distributed Energy Resources (DERs) plays important role in improvement of voltage profile to reduces the losses. Different optimization techniques have been proposed for finding the condition point of DERs [260]. The challenges that faced by transmission of HVDC with integration of other sources in national grid of Pakistan. It's proved that the crisis of energy in Pakistan can be minimized by using proposed HVDC technology [261]. In a MT HVDC structure a Mayfly Algorithm (MA) has proposed to increase the control efficiency of voltage source converter (VSC) by designing its parameters [262].

The concept of regional power connectivity has been explained through out Asia. The relationship of Asia and China has been explained in term of power connection [263]. The Europe 2020 infrastructure has been presented for development and prosperity of people, which lead to be sustainable growth of Europe country [264]. The zero CO_2 emission has been adapted by Australia country due to greater renewable sources and is exported to Asian country [265].

The solution for maximum power transfer across the boundaries of the country in Europe and Latin America. To reduce the transmission losses Ultra High Voltage Alternating Current (UHVAC) having voltage value is above 800 kV has been suggested [266]. The installation of HVDC grid of Europe along with Challenging tasks and advantages of HVDC have been discussed in [267], and proved that this will lead to maintain a union in Europe countries in term of electric power. The advantages of renewable energies to stabilize the economic situation of the country has bee discussed in [268]. The effect of political leadership of China and Russia on Asian super grid has been noted, which is main reason on the super grid infrastructure to share the power from both side to make the economy strong [269].

The researcher presented the green energy based on the first step of Northeast Asian Super Grid having less effect on environmental pollution. The electric vehicle play main role in reduction of CO_2 emission. The vehicle to grid (V2G) mode in electric vehicle application act as a back up source to provide power to the load during its peak demand. It support and stabilize the smart grid to keep better voltage profile under varying load conditions [270]. The effect of V2G technology has been studied in Modern Distribution Network (MDW). The reliability tool has been suggested to measure the reliability of MDW including V2G [271].

The plug in electric vehicle (PEV) consist of charging unit and HESS. The integration of different energy storage devices communication is depicted in Fig. (48) which is proposed for super grid infrastructure along with V2G concept. The Fig. (48) describes the flow of energy between different energy management system by using a common interface, that control and manage the flow of energy between various system. The various system such as energy management sys-

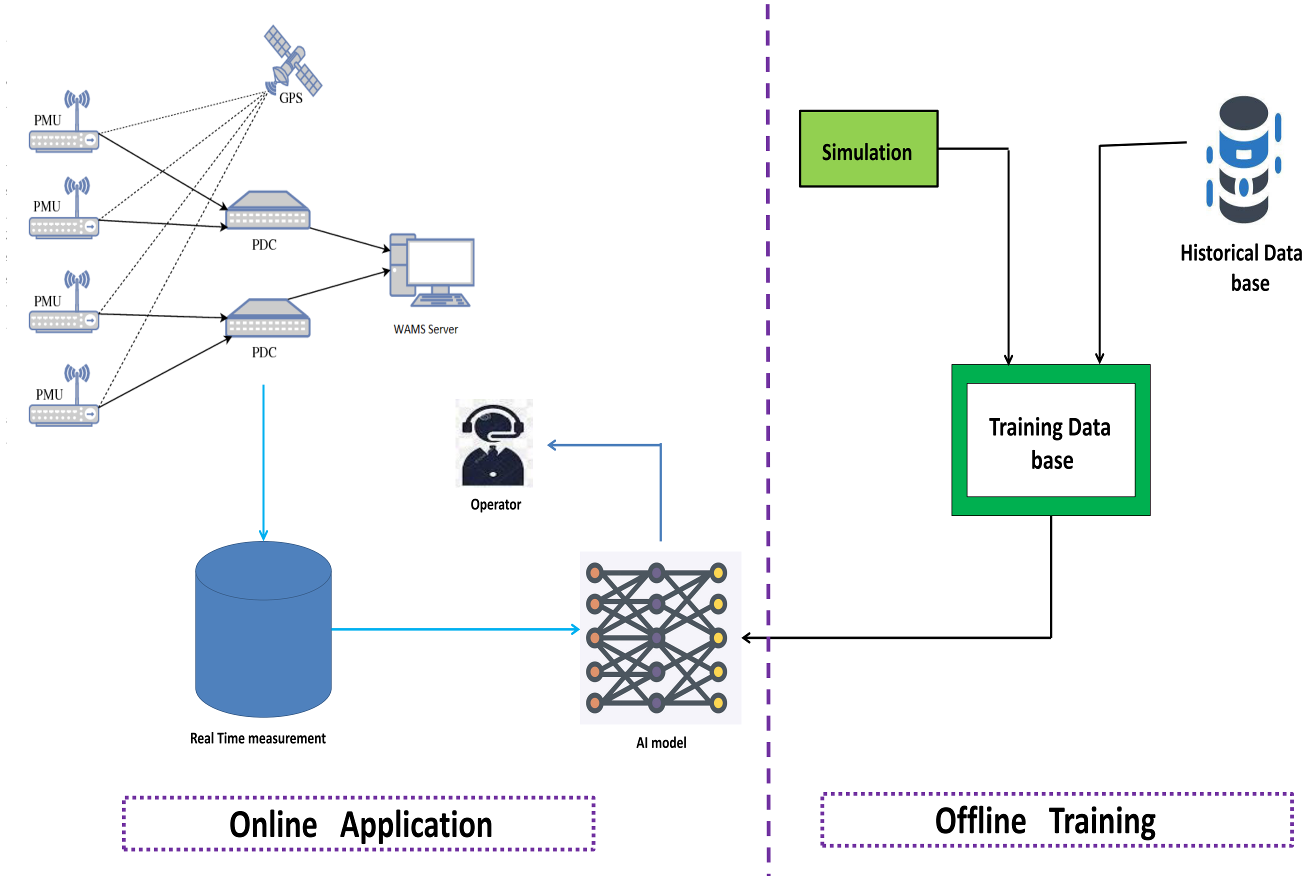


FIGURE 47. AI architecture model both online and off line.

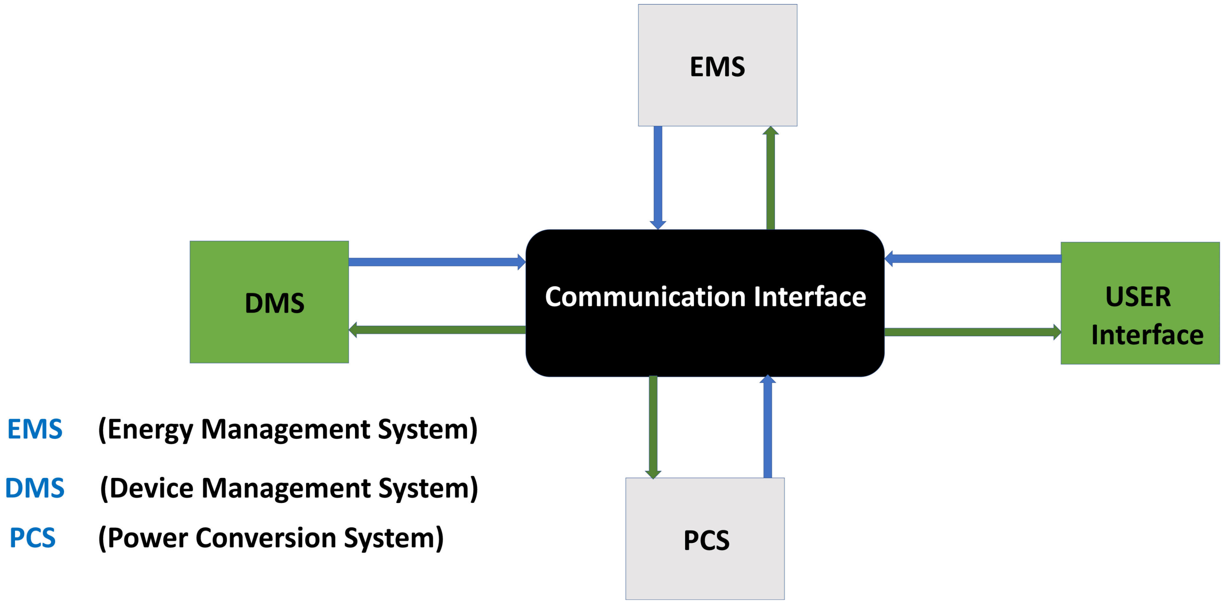


FIGURE 48. Communication of energy between storage devices.

tem (EMS), device management system (DMS) and power conversion system (PCS) are interconnected with user by a common communication interface. This topology is helpful by designing a hybrid energy management system in SSGs [272]. A linear programming algorithm has proposed for the DC power flow in both directions in charging and discharging mode of the battery. The solar panel and wind are considered to be DC source in the smart grid for the charging of the PEV battery [273]. Advanced Metering Infrastructure (AMI) has been installed in America for controlling of price. This technology has also lead to the smart grid system in the future [274]. A dual stage optimization technique based on day ahead optimization (DAO) and real time optimization (RTO) have been proposed for measuring charging and discharging time in V2G application at an office building [275]. The 5G V2G system has presented to emerged the 5G network with power grid to support far transmission network. The lightweight algorithms has employed for the security and privacy purpose in [276]. The different components of probabilistic load flow (PLF) have been discussed which have useful for the generation and distribution of PV power along with charging of EV [277]. The charging of electric vehicles may be possible by introducing Inductively Coupled Power Transfer (ICPT) technology. The circuitry parameters for ICPT have been designed for proper charging process [278], [279]. The technique for DC fast charging of electric vehicle has proposed and its impact on smart grid. A Frequency Containment Reserves (FCR) has employed for the frequency stabilization of power grid. The FCR affected the life of the battery [280]. In [281] proposed the FCR for both cases with and without battery in V2G application. Rain flow Counting (RFC) method has implemented to calculate the degradation factor.

The structure of super grid in china and US have been explored in [282]. The super grid in china consist of ultra high voltage alternating current (UHVAC) and line commutated converters high voltage direct current (LCC-HVDC), while the super grid in US consist of voltage source converter VSC HVDC [282]. The integration of smart African Super Grid system which are based on five African Power pools. A complicated controller has been designed for integration of these pools [283]. The effectiveness of Iraqi super grid has been explored by adding a solar power plant having capacity 1000MW [284]. The HVDC and HVAC links have been introduced for the comparison analysis and proposed a better solution to increase its performance. The stability of the system has been checked by performing the line and bus tests. The importance of power quality can not be ignored by proposing the structure of super grid because it directly impact the consumer in the form of voltage sag etc… [284]. The voltage sag is the major problem in power system that can be reduced by considering the CPDS such as DVR. Custom Power Devices (CPDs) have been for the distribution network to overcome the above mentioned problems. The Dynamic Voltage Restorer (DVR) is used to overcome the voltage sag occurring due to the unbalanced power grid [285]. The DVR has proposed for the distribution system due to its many advantages such as it keep the consumer online with maintaining high quality of voltage constant [286].

A fast decouple techniques has performed in power system tool to model the 330KV existing network along with Meshed 330kV super grid transmission line for the Nigerian system. It performed to reduces the transmission losses and increases the efficiency of the system [287]. The stability of bus has been checked by analysing fault on Benin IkejaWest Aiyede Oshogbo Benin (BIAOB) 330KV transmission connected to Nigerian grid. It's concluded that the reactive power is present on all buses while the lower value of voltage exist at Line-Line-Line-Ground (L-L-L-G) bus. Symmetrical components is the main part of transmission line [288], the scholars suggested that how the symmetrical components of transmission line is effected from tower structure along with the resistivity of ground. The resistivity of ground plays a major contribution on structure of tower according to locations [289]. The upgrading of radial 330KV to ring 750KV super grid system has been proposed for Nigerian grid because the ring system is low losses and more reliable than radial system. The Newton–Raphson Algorithm has employed to convert the existing 330KV to 750KV system [290]. The evaluation of bus voltage and efficiency of reactive compensation is carried out on 330kV networks of Ikeja West Transmission Company. It's observed that the station reactor greatly change the profile of voltage to improve the quality of power [291]. The researcher designed the electrical parameters along with mechanical structure of 750KV system for transmission of Extra High Voltage (EHV) to optimize the cost as well as the losses as compared to 330KV system in Nigeria [292].

The scholars proposed various strategies to converter smart grid system into Internet of Energy (IOE) for various communication purpose. The word IoE has used to represent companies and industries that need energy from the grid. It makes the decentralized system in which peer to peer communication possible through block chain technique [293]. The various techniques for saving of energy by utilities through block chain network in grid structure have been suggested in [294]. The wireless communication between different sections of grid and its application in future super smart grid have been explained, in which Various types of energies have emerged with each other by proposing the idea of Internet of Energy (IoE) like V2G technology, smart grid etc… [295]. The various application of block chain has been carried in modern grid system that make the grid is more smart and reliable along with enhancement of energy resources to fulfill the requirement of load at any condition due to fast communication that made possible by block chain [296].

The nonlinear controller has been proposed for the integration of renewable energy in DC grid having stable voltage and power profile to support frequency as just like in AC grid [302]. A nonlinear Backstepping controller has been suggested for the single phase grid connected PV system. It includes the three phase inverter and DC-DC converter. The controller designed for each converter is separately [300]. The supertwisting algorithm sliding mode controller (STASMC) has been proposed for the voltage control mode (VCM) and current control mode (CCM) of grid connected renewable

TABLE 2. Comparison with existing studies.

Year	Hardware	Communication Models	Security Protocols	Artificial Intelligence	Energy Management (G2V and V2G modes)	Controller Design	Optimization	Reference
2019	X	X	X	X	√	X	X	[269], [286], [62], [192]
2019	X	√	X	X	X	√	X	[143], [145]
2019	X	X	X	√	X	X	X	[243]–[245], [297]
2020	X	X	X	√	X	X	√	[214]–[230], [298]
2020	X	X	X	X	√	√	X	[260], [284], [191]
2021	X	X	X	X	√	X	√	[216], [223], [195], [196]
2021	X	√	X	√	X	X	X	[231], [263]
2021	X	√	X	X	X	X	X	[173], [233], [295], [299]
2022	X	X	X	X	√	X	√	[154], [228], [282]
2022	X	√	X	X	X	√	X	[144], [168], [300]
2023	X	X	X	√	√	X	X	[222], [237]
2023	X	X	√	√	X	X	√	[123], [124], [271], [275]
2023	√	X	X	X	X	√	X	[298], [300], [301]
2023	√	√	√	√	√	√	√	[*This Work*]

sources having single phase inverter [303]. The Adaptive supertwisting Controller has been designed to regulate the value of voltage to its required reference. The chattering effect has also minimized by proposed controller which decrease the losses in the system [304].

The proper Energy management systems (EMSs) has been introduced for the storage of energy from different renewable sources in grid. The optimization technique has proposed for the better usage of storage energy in grid. The integration of different renewable sources for transmission and distribution in smart or super grid is illustrated in Fig. (49) [305]. The fading Kalman filter algorithm has been developed for the communication in both way having far distance transmission of smart grid network. The proposed algorithm can also be used in super grid infrastructure for possible communication [306]. The voltage compensator and harmonic elimination technique have proposed for the reduction of sag in voltage and control of voltage profile respectively. The THD is lower than 5 % The lightening is very dangerous event for the electrical power system which may damage the components of power system, therefore the researchers designed surge arrester to arrest the lightening [308].

The effective way for controlling of power management has been discussed in developed country which should be to able to handle the control of power during power management [309]. The regulations of DC bus voltage in DC micro grid can be improved by proposed voltage modulated direct power control method. From the inner loop proved the stability of the system while the outer loop helps to regulate the DC bus voltage. The energy can be import and export to grid by using electric vehicle in G2V and V2G mode [310]. The Energy Monitoring System (EMS) in electric vehicle has been proposed to minimize the consumption of fuel along with reduction of CO_2 gas [311]. The computational intelligence (CI) technique has been suggested for the refrigeration system to increase the efficiency in order to reduce the heat losses and decreases the cost of the system. The proposed method has been compared with other AI technique such as ANN to proof the robustness of proposed algorithm [312].

The performance of photovoltaic system has been tested on small, medium and large scales according to the different locations and climate change in the world. The authors proposed seven different PV technologies for different weather conditions. The electrolysis of sea is used to provide green hydrogen by proposing a marine renewable energies [313]. It's proved that the proton exchange membrane electrolysis at sea level has best choice for gaining green hydrogen from the marine renewable energies [314]. Many methods have been described for the green and clean production of hydrogen at large scale in Morocco's. it's concluded that the electrolysis of alkaline earth water with renewable energy is best choice for generation of hydrogen in Morocco [315].

A dual-stage robust frequency risk-constrained unit commitment (FRCUC) has proposed for the smooth operation of system. The frequency violation risk has been considered to adapt the stability of the system. The proposed model has suggested for the HVDC system Which represented the better performance [301]. The comparison between

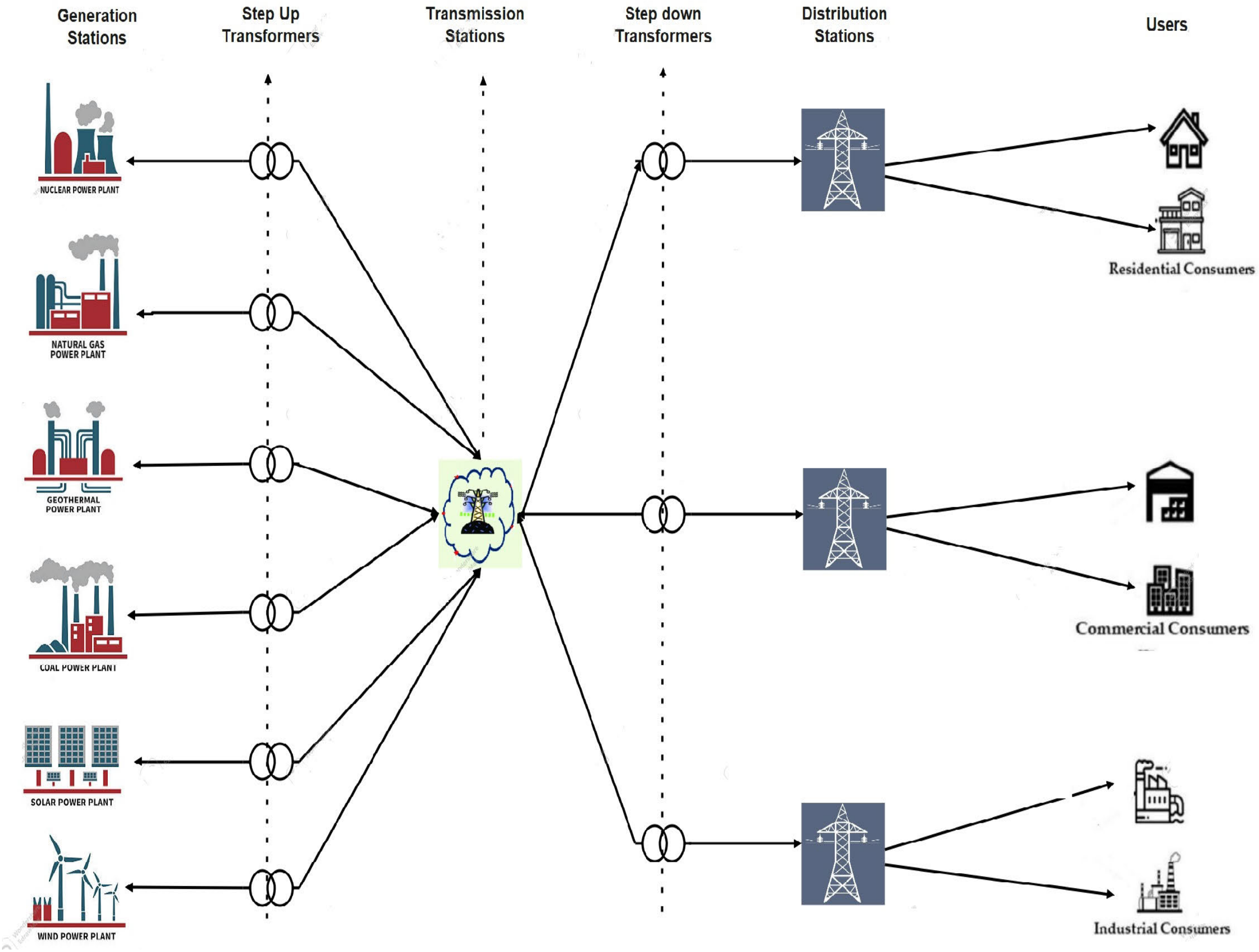


FIGURE 49. Integration of different renewable sources.

self-excited induction generator (SEIG) and permanent magnet synchronous generator (PMSG) have been highlighted by considering its application with renewable energy source. The performance of these both generator practically checked by using with micro hydro-turbine [316]. The parallel operation of Self-Excited Induction Generator (SEIG) for mini power generation in standalone. They have been tested experimentally without using any power electronic components. Capacitor bank has been taken online for excitation purpose of generator [317]. The three-phase Squirrel Cage Induction Machine (SCIM) has been used to create the setup for the single phase power through two capacitor methods in rural areas of India [318].

The relationship among renewable, non renewable energy, GDP and emissions of CO_2 have been studied in Vietnam. The wavelets analysis has been suggested for evaluating this relationship [319]. The world investment energy 2017 explained the way of decision taken by government, energy sector along with other financial departments. The issue related to energy has also explored for 2017 and beyond it [320].

The mechanism of HVDC has been discussed along with the control strategy for DC and AC system have also explored with help of DC circuit breaker [321]. The electromagnetic transient has detected by using Multi Level Converter (MPC) instead of half bridge circuit. The accuracy of proposed MPC has been checked under operating different fault condition [322]. The equivalent model of multilevel converter (MPC) for Hardware In Loop (HIL) simulation has been developed. HIL has proposed to the check the performance of converter in real time scenario, which has been employed for the project in China in [323]. The equivalent model of multilevel converter (MPC) has proposed for the multi terminal DC (MTDC) system. The proposed model and system have based on HVDC breaker [324]. The different social factor and risk have been mentioned that effect the infrastructure of super grid in Europe and US. A latest policy has been created to analyze and develop the structure of super grid [325]. The transmission system of energy in future (2040) has been explored for the Europe. The optimization tool has applied to defined the future transmission system based proposed European zonal model [326]. The renewable energy source like wind and solar have been optimized in term of cost based on weather data that can be applicable for year 2030 [327]. The Australia has sufficient source of energy that has fulfill its requirements from the fossil fuel. Therefore Australia grid export energy to Asian grid called Australian-Asian Grid (AAG). The connection of grid and green energy is the major step to lead towards the sustainability via Global Energy Interconnection (GEI) platform [252]. The highly highlighted the following fields such as smart grid, high voltage transmission system and interconnection of grid for the global world in the future [328]. The concept of Global grid has been studied that all grid system connected in global to one transmission system [329]. The green energy from renewable resources reduces the challenging task to Global grid transmission system. The various feature has defined that used the idea of Global grid in reality [330]. The socio-technical experiments has based on four various steps of energy transition that lead to energy democracy in South Africa [331]. The fault current for HVDC circuit breaker has proposed to interrupt the current in HVDC system. The procedure for fault current and its interruption have been measured by using different switching tests [332]. The low frequency alternating current (LFAC) has been proposed for transmission of wind energy for long distance. The technical issue related to LFAC has been discussed to evaluate the range of the distance [333]. The control mechanism of multilevel matrix converter has been noted under unbalanced grid condition [334]. A decoupled control algorithm has been designed for low frequency transmission system using multilevel converter. The current has been transferred from dq axis to DC signal to show the better performance [335]. The methods for implementation global grid has been proposed and it's concluded that HVDC is a best option for transmission of high voltage through long distance [336]. The concept of electrification has been introduced to reduces the deficiency of energy in Africa. It's proposed the renewable energy for transmission and distribution for reliability of the super grid [337]. The the West African power system model has proposed to model financial electric market at which supply the electricity outside the border. It will estimate the cost of generation and other factors [338].

In nutshell, we have studied many articles in the literature that summarized in Table [2].

XII. COMPARISON WITH EXISTING SOLUTIONS

In this section we have presented a comparative analysis of proposed work with existing literature in Table [2]. It analyzes the reviews on the presence of various parameters that are depicted in tabular form. The proposed review article cover all topics that supports the infrastructure of super grid to minimize the crises of energy through globe.

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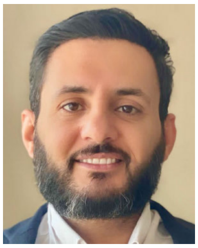

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