Chapter 2

Literature Review

2.1 Introduction

This chapter reviews the convention power plant control and control techniques to accomplish a balanced operation. The control technique implementation in conventional power plant such as Automatic generation control (AGC) or Load Frequency Control (LFC) will be discussed and to implement a Tie-Line Frequency Bias Control for a two stage interconnected system. The impact of stand-alone, Grid connected and hybrid system implementation using Renewable Energy Sources (RES) generation will be analyzed to identify the gap in research. Which forms the basis of the thesis.

The problems of establishing a normal operating state with a constant output voltage and frequency and optimum scheduling of generation in conventional power system were extensively investigated and several solutions were proposed in the literature which will be discussed in detail in the Section 2.1.1. Tie-line control techniques proposed in the literature for conventional power system will be studied. This review focuses on the control techniques implementation of interconnected PV-Wind hybrid power system to keep the system in the steady-state under varying environmental and load condition. The objective of the control strategy is to generate and deliver power in an interconnected system as economically and reliably as possible while maintaining the voltage and frequency.

Changes in real power affect mainly the system frequency, while the reactive power is less sensitive to changes in the frequency and is mainly dependent on changes in voltage magnitude. Thus, the real and reactive powers are controlled separately. The Load Frequency Control (LFC) loop controls the real power and frequency and the Automatic Voltage Regulator (AVR) loop regulates the reactive power and voltage magnitude. Load frequency control (LFC) has gained in importance with the growth of interconnected systems and has made the operation of interconnected systems possible.

The role of Automatic generation control (AGC) in power system operation, with reference to tie-line power control under normal conditions, will be discussed. Finally, the requirement of reactive power and voltage regulation and the influence on the stability of both speed and excitation controls, with the use of suitable feedback signals, are examined. The following subsection Power plant control will be discussed in Detail.

2.1.1 Power Plant Control Modes:

The control of the steam generator and turbine in a power plant are nearly always considered to be a single control system. This is true because of the two units, generator, and turbine, operate together, the two subsystems must operate in unison under both steady-state and transient conditions [28–33]. The different control modes commonly used by the industry are

1. **The turbine following control mode:** In this control mode, a load demand signal is used to adjust the boiler firing rate and the fluid pumping rate. As the boiler slowly changes its energy level to correspond to the demand signal, the pressure changes at the throttle (the turbine control valves). This method is also referred as “base boiler input” and “admission pressure control” systems (the latter mostly in Europe).

2. **The boiler following control mode:** This control mode is sometimes called the “conventional mode” or (in Europe) the combustion control mode. This control scheme divides the control function such that the governor responds directly to changes in load demand. The response is an immediate change in generator load due to a change in turbine valve position and the resulting steam flow rate. The boiler “follows” this change and must not only “catch up” to the new load level, but also must account for the energy borrowed or stored in the boiler at the time the change was initiated. This type of control responds quickly, utilizes stored boiler energy effectively, and is generally stable under constant load.

3. **The co-ordinate control mode:** Most modern thermal generating units employ a control scheme that is usually called an integrated or coordinated control system. This type of system simultaneously adjusts firing rate, pumping rate, and turbine throttling in order to follow changes in load demand. In this type of control, both pressure and generated output are fed back to the control of both boiler and turbine. In this manner, it is possible to achieve the stable and smooth load changes of the turbine following mode and still enjoy the prompt response of the boiler following mode. This is accomplished by making maximum use of the available thermal storage in the boiler. Both pumping and firing rates are made proportional to the generation error so that these efforts are stabilized as the load approaches the required value. Pressure deviation is controlled as a function of both the thermal storage and the generation error.

2.1.2 Generator, Load and Prime-mover Model:

2.1.2.1 Model of Generator:

Figure 2.1 shows the mechanical and electrical torque developed in a generating unit.The relationship is expressed as

$$P_{net} = P_{mechanical} - P_{electrical} \tag{2.1}$$

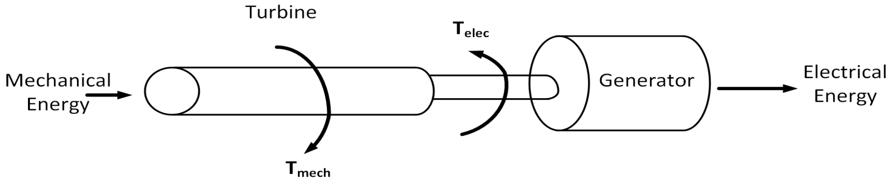

FIGURE 2.1: Turbine and Generator torque

Which is expressed in terms of steady-state and deviation term,

$$P_{net} = P_{net0} + \Delta P_{net} \tag{2.2}$$

where,

$$P_{net0} = P_{mechanical0} - P_{electrical0} \tag{2.3}$$

$$\Delta P_{net} = \Delta P_{mechanical} - \Delta P_{electrical} \tag{2.4}$$

Then,

$$P_{net} = (P_{mechanical0} - P_{electrical0}) + (\Delta P_{mechanical} - \Delta P_{electrical}) \tag{2.5}$$

$$\begin{aligned} \Delta P_{mechanical} - P_{electrical} &= \omega_o I \frac{d}{dt}(\Delta\omega) \\ &= M \frac{d}{dt}(\Delta\omega) \end{aligned} \tag{2.6}$$

$$\Delta P_{mechanical} - \Delta P_{electrical} = M_s \Delta\omega \tag{2.7}$$

2.1.2.2 Mathematical modeling of Load:

The loads on a power system consist of a variety of electrical devices. Some of them are purely resistive, some are motor loads with variable power frequency characteristics, and others exhibit quite different characteristics. Since motor loads are a dominant part of the electrical load, there is a need to model the effect of a change in frequency on the net load drawn by the system. The relationship between the changes in load due to the change in frequency is given by

$$\Delta P_{Lfreq} = D\Delta\omega or D = \frac{\Delta P_{LFreq}}{\Delta\omega} \tag{2.8}$$

where D is definitive as the ratio of % deviation in load to % deviation in frequency.

2.1.2.3 Model of Prime-Mover:

The steam turbine or a hydro-turbine acts as prime mover to the generator unit. The simplest prime-mover model, the non-reheat turbine, will be used. The model for a non-reheat turbine, relates the position of the valve that controls emission of steam into the turbine to the power output of the turbine. The combined prime-mover-generator-load model for a single generating unit can be built as shown Figure 2.2

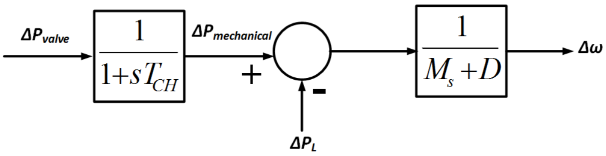

FIGURE 2.2: Prime-mover model

2.1.3 Model of Governor:

In defining the model of the governor operation, the normal speed is considered as 100% speed and the full load as 100% load. There are two modes of operation.

- Isochronous operation,
- Droop Mode Operation.

2.1.3.1 Isochronous Operation:

The governor maintains a constant speed from no load to full load. If the output of speed-sensing system is directly connected o the valve via a direct link, the frequency will never be adjusted to nominal value. In order to make the frequency error zero, actual speed is compared with desired speed and the error is minimized [34–40]. The speed governing system is shown in Figure 2.3. A prime mover and a generator, operating in the isochronous mode can maintain the desired output frequency, regardless of load changes as long as the prime mover capacity is not exceeded. This mode is normally used in isolated systems or when one generator is required to respond to the load changes.

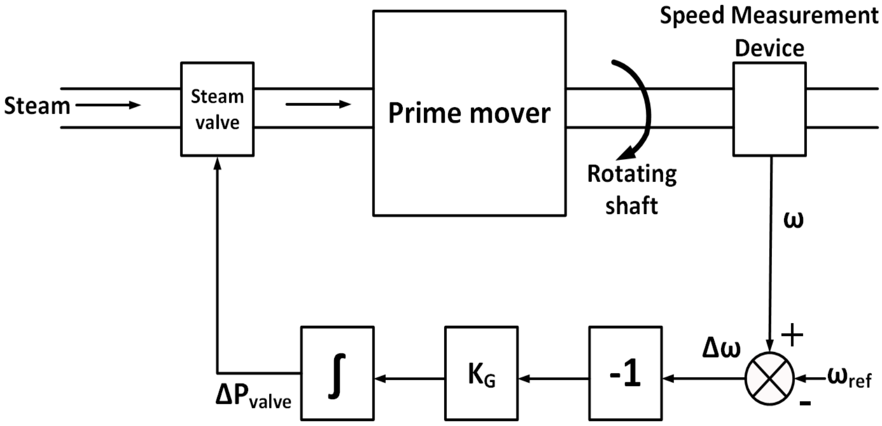

FIGURE 2.3: Isochronous Governor

2.1.3.2 Droop Mode Operation:

The isochronous mode of operation shown in Figure 2.3 fails to operate when two or more generators are synchronized to same system. To run 2 or more units in parallel on a common system, a feedback signal is provided to the governors. This will minimize the speed error for different value of generation.

This can be established by introducing a feedback loop near the integrator as illustrated in Figure 2.4. The block diagram is shown in Figure 2.5, where the net gain of 1/R for the governor and a time constant T_G.

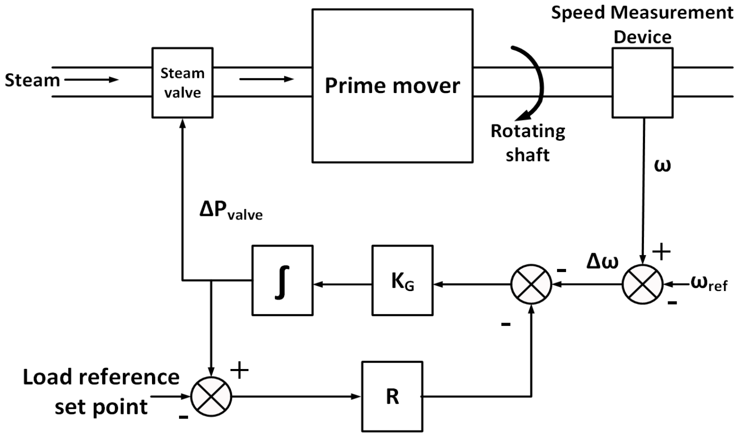

FIGURE 2.4: Governor with speed-droop feedback loop

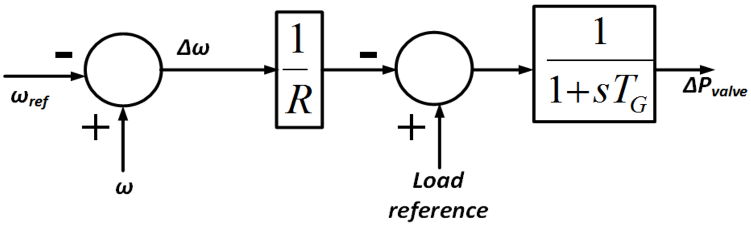

FIGURE 2.5: Block diagram of governor with droop

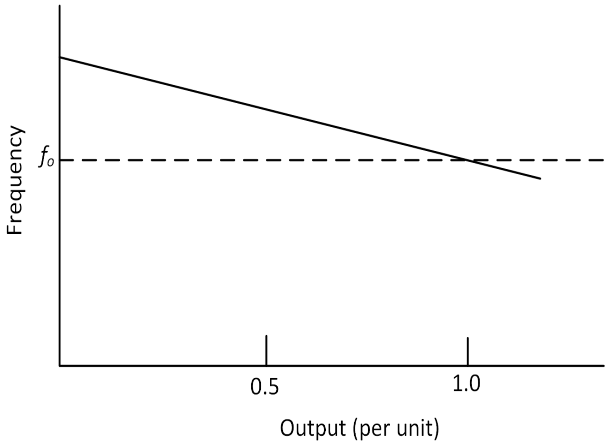

FIGURE 2.6: Speed – Droop characteristics

The feedback with R in the governor characteristic is shown in Figure 2.6. The value of R determines the slope of the characteristic.

considering 2 generators with different droop are adjoining a power system, there will always be a unique frequency, at which they will share a load change between them. This is illustrated in Figure 2.7, showing two units with drooping characteristics connected to a common load. Figure 2.8 illustrates

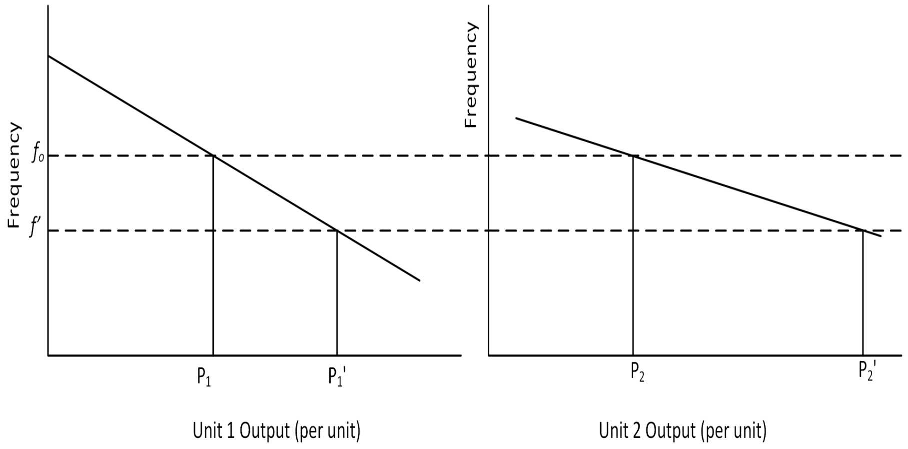

FIGURE 2.7: Allocation of unit outputs with governor droop

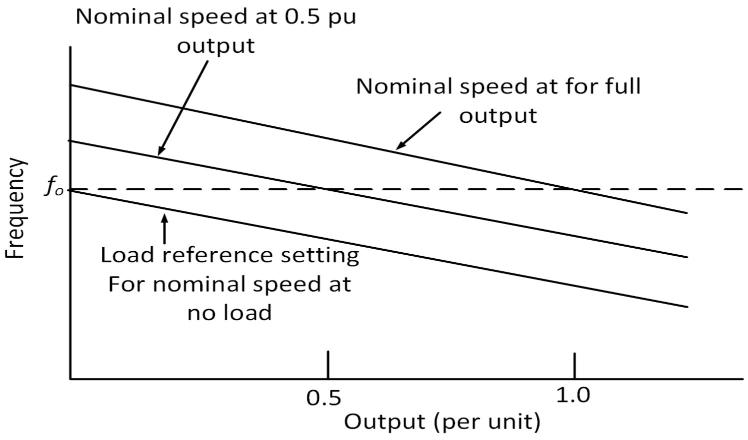

FIGURE 2.8: Speed-changer settings

speed changer setting of governor. The basic control input to a generating unit as far as generation control is concerned is the load reference set point. By adjusting this set point on each unit, the desired unit dispatch can be maintained while holding system frequency close to the desired nominal value. Therefore, R is equal to pu change in frequency divided by pu change in unit output. That is,

$$R = \frac{\Delta\omega}{\Delta P}\, pu \tag{2.9}$$

The block diagram of a governor-prime-mover rotating mass/load model is as shown in Figure 2.9. Suppose that this generator experiences a step increase in load,

$$\Delta P_L(s) = \frac{\Delta p_L}{s} \tag{2.10}$$

The steady-state value of $\Delta\omega(S)$ may be found by

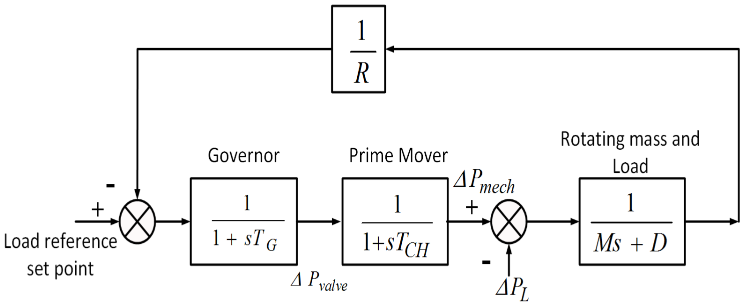

FIGURE 2.9: Block diagram of single area system

$$\begin{aligned}\Delta\omega StaedyState &= \int_{s\to 0} s\Delta\omega(s)\\ &= \frac{-\Delta P_L}{\frac{1}{R}+D}\end{aligned} \tag{2.11}$$

If D were zero, the speed change can be expressed as

$$\Delta\omega = -R\Delta P_L \tag{2.12}$$

If several generators (each having its own governor and prime mover) were connected to the system, the frequency change would be

$$\Delta\omega = \frac{-\Delta P_L}{\frac{1}{R_1}+\frac{1}{R_2+\ldots+\frac{1}{R_n}+D}} \tag{2.13}$$

A block diagram representing of interconnection can be drawn as in Figure 2.10. A group of generators coupled closely will swing together and may be replaced by a single equivalent generator. The generator turbines also tend to have the same response characteristics. Such generators are said

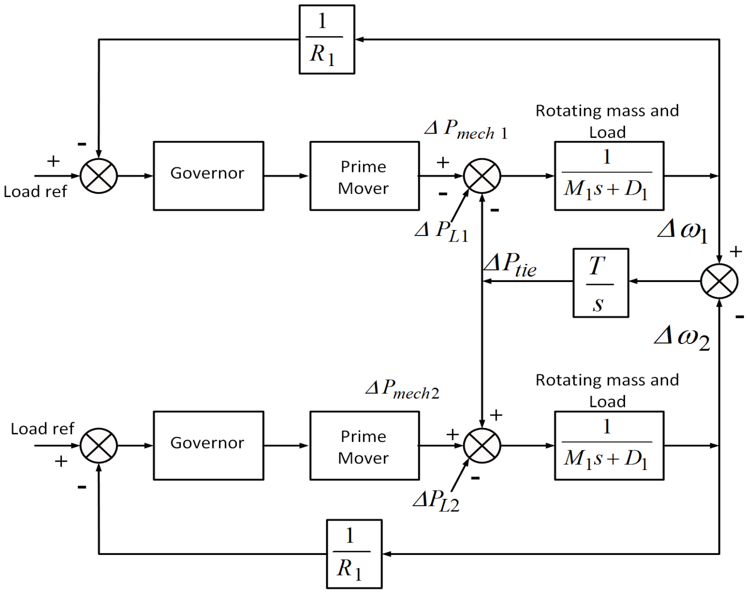

FIGURE 2.10: Block diagram representation of interconnected areas

to be coherent and the system is called a control area. When different control areas are connected, the objectives of the AGC are as follows:

1. Hold the system frequency close to the nominal value of 50 Hz.

2. To maintain a correct value of power interchange between control areas.

3. Maintain generation of each unit at the most economical value.

In order to maintain frequency constant, both the governor and supplementary controls are required for stable and economical operation. The regulation may be manual or automatic and the techniques used are

1. Flat-frequency control,
2. Parallel frequency control,
3. Flat tie-line control,
4. Tie-line bias control.

2.2 Literature survey on Automatic Generation Control(AGC) / Load Frequency Control (LFC) / Tie-line control in Conventional Power Generation:

Various researchers have worked towards attaining the finest control by solving the problems of the interconnected system over the years. A few major control techniques from the literature are presented belowProf. J Nanda et. al [41–65] have worked extensively on AGC of interconnected two-area, multi-area systems from 1977 - 2011 and proposed various control techniques such as PID, Fuzzy logic control, Neural Network, Fuzzy-ANN, several optimizing techniques algorithm to have a better load frequency control and power regulation in the interconnected power system.

Lalit Chandra Saikia et.al. [66–89]have worked towards load frequency control in multi-area interconnected system and proposed various control techniques as cascade integral and proportional derivative, moth-flame optimization, biography-based optimized 3 Degree Of Freedom (DOF) - Proportional Integral Derivative (PID) controller, Maiden application of hybrid pattern search, PID, classical, non-integer order PID, fractional order controller, Fuzzy logic based Integral double derivative (IDD) controller, Bacterial Foraging, several types of classical controllers, Firefly optimization, BES and Cuckoo search, neuro-fuzzy multilayer perception neural network, bacterial foraging based fractional order PID (FOPID) controller, non-integer order controller. Different researchers have proposed similar techniques with a different combination of conventional generations in terms of the multi-area system.

[90] The study formulates a security-constrained multi-objective framework with unit commitment in multi-area electricity markets for day-ahead joint market-clearing. The dynamic and inertial characteristics of the power system are derived and incorporated into the market-clearing procedure in order to preserve power system security from the frequency viewpoint. In addition, two novel objective functions (tie-flow deviation index and Rocof index) besides the frequency-dependent social welfare and frequency excursion

index have been defined to control the static frequency, the rate of change of frequency (Rocof) and also the tie-line power flows, following the occurrence of a contingency. Comprehensive analysis tools for multi-area power systems and also pre- and post-contingency intervals are presented to verify the characteristics of the proposed model. The developed multi-objective programming is analyzed through two case studies, a three-area system scheduled over 1hr and the IEEE two-area reliability test system over 24hr. It has been shown that the scheduling of energy and reserve services can be performed more effectively if the system frequency is considered in the market-clearing process. The proposed model can reconcile the need for reasonable total generation cost with concern for the independent system operator's responsibilities about the pre- and post-contingency tie-line power flow control and system security.

[91] A model predictive controller (MPC) for load frequency control (LFC) of an interconnected power system is investigated. The MPC is based on a simplified system model of the Nordic power system, and it takes into account limitations of tie-line power flow, generation capacity, and generation rate of change. The participation factors for each generator are optimization variables, and suggestions are made as to how one can ensure tie-line power transfer margins through slack variables, and pricing information through the objective function. The solution of MPC for LFC is completed by including a Kalman filter for state estimation. The presented MPC is compared against a conventional LFC/AGC scheme with proportional-integral (PI) controllers. Simulations show that the MPC gives better frequency response while using cheaper resources.

[92] The control strategy for frequency in Northeast power grid in China and power flow in tie line between Northeast and North China power grid are described. Based on statistical analysis of frequency control in Liaoning power grid in 2001 and 2002, analyzed and summarized the causes of the frequency over the limit. Combining the real-time records of the frequency and tie-line power flow during the several trips of some major generating units in this area in 2002, the load flow variations in the regions in the Northeast power grid are investigated and the natural frequency characteristic coefficients of Liaoning power network and Heilongjiang power network are calculated.

2.3 Literature review on Impact of RES Penetration into grid / Stand-alone operation/Hybrid system:

With the evolution of alternative, green source of the generation known as Renewable generation i.e. Solar Photovoltaic (PV), The Wind, Fuel Cell etc. The impact of penetration these RES generation into the conventional system is investigated by [93–98] and the LFC techniques for the RES with diesel generator, micro grid.

Various researchers [99–106] have worked towards coordinate control method for minimizing the output voltage fluctuations of the PV system caused by varying environmental conditions. Estimation of PV power generated, low-frequency and high-frequency components using correlative method, grid-integrated distributed PV system, LFC of distributed energy storage system integrated with distributed PV and electric vehicle, LFC of diesel generator and PV system with PI and FGSPI (Fuzzy Gain Scheduling PI) controller, power management of PV-Fuel cell system.

A few works related to LFC of wind power generation [107–114] have proposed LFC for Battery and generator feed-forward control, new optimized PID controller and RFBs (redox flow batteries), LFC of wind power system using Kalman filter, LFC for two-area interconnected power system with DFIG by Ant colony, disturbance observation.

[115, 116] A survey on hybrid power system stating different control strategies, configurations, grid side and load side problems. [117–119] has worked toward optimal sizing and reliability of a PV-wind hybrid power system using autoregressive moving average, design, and implementation of grid tie inverter and voltage control of the hybrid system.

2.4 Literature review on Hybrid Power System

The technology to harness power from the Renewable Energy Sources (RES) such as The Wind, Photovoltaic (PV), Fuel-cell etc.. is growing exponentially. This technology is gaining importance in order to meet the gap between energy demand and generation. Further, the impact of global warming necessitated a clean and this green energy generation technique which is possible through RES generation which evolved to control the carbon emission. Among different RES generation's Wind Generation and PV based generation are well-established technologies all over the world. They provide a wide opportunity to utilize the available solar and wind resources. Further, this RES generation is selected depending on the geographical location and environmental conditions. However, it has an unpredictable nature of generation as the power generated depends on the environmental conditions. In order to have a sustainable power generation, a Hybrid RES power generation technique is employed.
The PV, The Wind and different hybrid power installation in India and worldwide are tabulated in Table 2.1 [120]. Each country has a large number of RES power installation out of which a few were represented in the Table 2.1 and it can be comprehended that the most of the hybrid power installation were in the combination of any **one** RES with diesel generator or battery storage devices. A few countries have PV-wind-battery/diesel generator hybrid installations, however, India has one PV-Wind hybrid power system installed in Leh district in Jam mu and Kashmir.

Table 2.2 provides details on growth of state wise solar power installed capacity in India [121, 123]. Table 2.3 provides the information of state wise wind power installation capacity in India [122, 124]. India has set an ambitious target of reaching 175 GW of installed capacity from renewable energy sources by the year 2022[125]. This includes 60 GW from wind power, 100 GW from solar power, 10 GW of biomass power and 5 GW from small hydro power. A target of 16660 MW grid renewable power (wind 4000 MW, Solar 12000 MW, small hydro power 250 MW, bio-power 400 MW and waste to power 10 MW), has been set for 2016-17[125]. Besides, under the off-grid renewable system, targets of 15 MW

TABLE 2.1: PV, Wind and Hybrid power installation in different Countries over the world [120]

Country	Location	Type of RES	Capacity	commissioned
British, Saint Helema	Ascesion Island	Wind-diesel hybrid	1.65 MW	2010
Cape Verde	Santiago Island	PV, Wind	2.5 MW PV, 9.35MW Wind	2010
	Saovicente Island	Wind	5.95 MW	2011/12
	Sai Island	Wind	7.65 MW	2011/12
	Boa Vista Island	Wind	2.5 MW	2011/12
Mauritius	Rodrigues Island	Wind	1.1 MW	2010
	Flacq	Solar-diesel hybrid	1.2 MW	2015
Anguilla	CuisinArt Golf Resort & Spa, Rendezvous Bay	Solar -diesel hybrid	1 MWp	Sep. 2014
British Virgin Island	Necker Island	PV & Wind	700 kWp - solar, 300 kW - wind	
Bahamas	Overy onder cay Island	PV-Wind-diesel hybrid	300 kWp - wind 375 kWp PV	2014
Canada	Ramea	wind-diesel hybrid	390 kWp	2004
USA	Alcatraz	Solar-diesel hybrid	307 kWp	2012
Ecuador	San Cristobal Island	Wind and Solar	2.4 MW wind, 12 kW solar	2014
UAE	Al Yassat	PV-diesel hybrid	800 kW	2014
Japan	Miyako Island	PV-Wind-diesel hybrid	4.2 MW wind, 4 MW PV	2015
	Yonaguni	PV and Wind	1.2 MW wind, 150 kW PV	2014
Maldives	Male	PV-diesel	1.21 MWp	2015
	Gastinohu Island	Solar-diesel hybrid	1 MWp	2015
China	Dongap Island	PV-Wind with storage device	50 kW Wind, 200 kW PV	2015
India	**Leh District**	**Solar-wind hybrid**	**6 × 10 kW**	
Bahamas	Exuma	Solar-Wind-diesel hybrid	240 kW solar, 15 kW wind	2009
Australia	King Island	PV and Wind	2.45 MW wind, 0.2 MW PV	
Newzeland	Ross Island, Antartica	Wind-diesel hybrid	1 MW	2010
Denmark	Samso	wind	11 MW onshore, 23 MW offshore	
Spain	El Hierro, Garafia, La Palma, Fuencaliente, La Palma	Wind	11.5 MWp, 1.6 MWp, 2.7 MWp	2011
Portugal	Graciosa	PV-Wind	4.5 MW wind, 1 MW PV	
Greece	Kythnas	Wind-PV	500 kW wind, 100 kW PV	1998 - wind 1983- PV
Germany	pellworm	PV-Wind with storage	771 kWp PV, 300 kW wind	2006
UK	orkney Island	Wind	4.5 MW	2010

waste to energy, 60 MW biomass non-bagasse co-generation, 10 MW biomass gasifiers, 1.0 MW small wind/hybrid systems, 100 MW solar Photovoltaic systems, 1.0 MW micro hydel and 100,000 nos. family size biogas plants have been set for 2016-17. Various policy initiatives have been taken to achieve this

TABLE 2.2: ”Growth of Solar Power installed capacity in India” [121]

”State”	**”MW as of” ”31-MAR-2015”**	**”MW as of” ”31-MAR-2016”**	**”MW as of” ”31-JAN-2017”**
”Rajasthan”	”942.10”	”1,269.93”	”1,317.64”
”Punjab”	”185.27”	”405.06”	”592.35”
”Uttar Pradesh”	”71.26”	”143.50”	”269.26”
”Uttarakhand”	”5.00”	”41.15”	”45.10”
”Haryana”	”12.80”	”15.39”	”73.27”
”Delhi”	”5.47”	”14.28”	”38.78”
”Jammu and Kashmir”	”0.00”	”1.00”	”1.00”
”Chandigarh”	”4.50”	”6.81”	”16.20”
”Himachal Pradesh”	”0.00”	”0.20”	”0.33”
”Northern Region”			**”2,353.93”**
”Gujarat”	”1,000.05”	”1,119.17”	”1,159.76”
”Maharashtra”	”360.75”	”385.76”	”430.46”
”Chhattisgarh”	”7.60”	”93.58”	”135.19”
”Madhya Pradesh”	”558.58”	”776.37”	”850.35”
”D&N”	”0.00”	”0.00”	”0.60”
”Goa”	”0.00”	”0.00”	”0.05”
”Daman & Diu”	”0.00”	”4.00”	”4.00”
”Western Region”			**”2,580.37”**
”Tamil Nadu”	”142.58”	”1,061.82”	”1,590.97”
”Andhra Pradesh”	”137.85”	”572.97”	”979.65”
”Telangana”	”167.05”	”527.84”	”1,073.41”
”Kerala”	”0.03”	”13.05”	”15.86”
”Karnataka”	”77.22”	”145.46”	”341.93”
”Puducherry”	”0.20”	”0.20”	”0.03”
”Southern Region”			**”4,001.85”**
”Bihar”	”0.00”	”5.10”	”95.91”
”Odisha”	”31.76”	”66.92”	”77.64”
”Jharkhand”	”16.00”	”16.19”	”17.51”
”West Bengal”	”7.21”	”7.77”	”23.07”
”Sikkim”	”0.00”	”0.19”	”0.01”
”Eastern Region”			**”214.14”**
”Assam”	”0.00”	”0.00”	”11.18”
”Tripura”	”5.00”	”5.00”	”5.02”
”Arunachal Pradesh”	”0.03”	”0.27”	”0.27”
”Mizoram”	”0.00”	”0.00”	”0.01”
”Manipur”	”0.00”	”0.00”	”0.10”
”Meghalya”	”0.00”	”0.00”	”0.01”
”Nagaland”	”0.00”	”0.00”	”0.50”
”North Eastern Region”			**”17.09”**
”Andaman & Nicobar”	”5.10”	”5.10”	”5.40”
”Lakshadweep”	”0.75”	”0.75”	”0.75”
”Others”	”0.00”	”58.31”	”61.70”
”Islands and others”			**”67.85”**
”Total”	**”3,743.97”**	**”6,762.85”**	**”9,235.24”**

TABLE 2.3: ”Installed wind capacity by state in India as of 19 October 2016” [122]

”State”	**”Total Capacity (MW)”**
”Tamil Nadu”	”7,684.31”
”Maharashtra”	”4,664.08”
”Gujarat”	”4,227.31”
”Rajasthan”	”4,123.35”
”Karnataka”	”3,082.45”
”Madhya Pradesh”	”2,288.60”
”Andhra Pradesh”	”1,866.35”
”Telangana”	”98.70”
”Kerala”	”43.50”
”Others”	”4.30”
”Total”	”28,082.95”

target. The country has already crossed a mark 26.8 GW of the wind and 7.6 GW of solar power installed capacity during May 2016 [126, 127]. State wise renewable energy potential in the country was tabulated and the target set for the various renewable energy sources for the next three years are tabulated in Table 2.4 [128]. It is observed that in India, individual RES have been commissioned, however, an installation of the hybrid system is limited. Studies have to be conducted to realize the capability of the Hybrid power system. Subsequently, PV and Wind hybrid power system are chosen for the study. The two RES generations will be configured to operate at the same point of integration. The second important aspect would be related to the sizing – which would depend on the resource characteristics. In order to achieve the benefits of the hybrid plant in terms of optimal and efficient utilization of transmission infrastructure and better grid stability, reducing the variability in renewable power generation is important. In the locations where the wind power density is quite good, the size of the solar PVs capacity to be added as the solar-hybrid component could be relatively smaller. On the other hand, in the case of the sites

TABLE 2.4: Target set for the various RES [128]

Source	**2016-17**	**2017-18**	**2018-19**
Solar Power (MW)	12,000	15,000	16,000
Wind Power (MW)	4000	4600	5200
Biomass (MW)	500	750	850
SHP (MW)	225	100	100
Total (MW)	16725	20450	22150

where the wind power density is relatively lower or moderate, the component of the solar PV capacity could be relatively on a higher side.

2.5 Gap in Research

From the literature the AGC or LFC techniques utilized in conventional power system were investigated for the interconnected systems such as thermal-hydro, wind-diesel, PV-diesel, Wind-SMES, Wind-PV-Diesel and combination of RES with energy storage devices.

There is a scope towards investigation of a Hybrid system with out any storage device and developing a Tie-line Frequency bias control technique for interconnected PV-Wind Hybrid power system. Based on the study following objectives were considered to investigate the Tie-line Frequency bias control technique.

1. Developing a Mathematical model of a hybrid power system consisting of interconnected Solar Photovoltaic (PV), Wind power generation without storage devices.

2. A Fuzzy Logic Control (FLC) based Maximum Power Point (MPP) tracking algorithm is implemented to improve the performance of the system. To investigate the dynamic response of the FLC under different scenarios of load demand and environmental conditions using MATLAB, Simulink.

3. Based on conventional Load Frequency Control (LFC) / Automatic Generation Control (AGC) the LFC technique for the PV-Wind hybrid system will be studied i.e. Discrete PLL, Droop Characteristics based control techniques.

4. To study of Discrete PLL based Load Frequency Control (LFC) of the stand-alone PV-wind hybrid power system. Performance analysis of the controller under varying environmental and load conditions. A comparative analysis of prediction techniques of wind speed and solar illumination.

5. To study the Droop characteristics based LFC and comparing the performance of the LFC with Discrete PLL based technique to obtain the better control technique.

6. Based on the results, Implementation of Flat Tie-Line frequency control of Interconnected PV-Wind Hybrid Power system.

2.6 Summary:

From the literature survey to overcome the backdrop and to improve the effective use of RES generation a new topology known as the Hybrid system is gaining importance. A Hybrid power system is a combination of different RES generations with or without storage device. The RES generations are selected depending on the geographical conditions of implementation. A control implementation for interconnected hybrid power system such that the power generated from one source compliments the other, by which Maximum power from RES generation can be utilized effectively. In such case storage element can be eliminated from the system forms the motivation for the research.

considering various parameters in the design of a Tie-line frequency-bias controller which can achieve the task of maintaining the voltage and frequency of the system constant with real time data of environmental conditions measured at the location as input and under different loading conditions. No research was specifically focused on the interconnection of non-conventional energy sources and designing a tie-line frequency-bias control utilizing the real-time data of the environmental conditions. The next chapter will discuss the modeling of PV based generation in the proposed Hybrid Power System.