Prospect of renewable energy sources and integrating challenges in Victoria, Australia

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***Abstract*—The Australian Government has targeted 20% of electricity generation from renewable energy sources by 2020. The 20% renewable energy target (RET) for Australia will be around 45000GWH in 2020. Renewable energy of Victoria also includes as part of support to achieve 20% RET in Australia. In Victoria wind and solar resources are abundant as compared to other sources of renewable energy. Solar radiation and wind speed data for Victoria State was collected from NASA surface meteorology and solar energy web site. A feasibility analysis has been carried out to explore the potentialities of wind and solar energy for Victoria State using hybrid optimization model of electric renewable (HOMER) software. This paper also represents the estimation analysis of RET for Victoria and describes the integrating challenges of renewable energy sources to the utility grid.**

Keywords—Renewable energy; Hybrid power system; economic anlysis; environmental analysis; RET.

I. INTRODUCTION

The Australian government has targeted 20% of electricity generation from renewable energy in 2020 [1].The renewable energy target (RET) has categorized into two schemes; namely large scale renewable energy target (LRET) and SRES (small scale renewable energy scheme). LRET supports large scale RE projects, like solar farm, wind farm, bio energy, and hydro power projects, whereas SRES supports solar PV, solar heaters in households and small business [1]. A report presented by the Climate Change Authority reviewing the national RET scheme forecasts a future national energy demand to 225 TWH in 2020 with a 45000 GWH contribution from renewable energy sources. The bulk of the contribution for the RET will be achieved through LRET which will contribute 41000 GWH [1, 2].

With the introduction of the national RET all individual RET set at the state level including the targets for the state of Victoria were rolled into the national target. The state of Victoria needs to make a significant contribution to help achieve the targeted 20% generation from renewable energy sources. This paper presents an estimation analysis based on the current annual consumption for Victoria [3]. It also presents a feasibility study on LRET using wind and solar generation that investigates the economic and environmental benefits of renewable energy (RE). It also discusses the challenges of integrating the power produced from the renewable energy sources to the grid.

This paper is organized as follows: section-II discusses the current RE scenario for Victoria; section-III discusses the availability of solar and wind in Victoria; section-IV presents the details of hybrid power system (HPS) model; section-V describes HPS simulation and results analysis using HOMER; section-VI discusses the challenges of integrating power generated from renewable energy sources to the grid; section-VII concludes the paper with future directions.

II. RENEWABLE ENERGY SCENARIO FOR VICTORIA

This section discusses the status of installed capacity and actual renewal power generation of Victoria in past and present conditions [4, 5].

In Victoria; solar, wind, bio energy, hydro power and tidal wave are existing sources of generation. The solar and wind resources are more abundantly available when compared to other renewable energy resources. Renewable power generation installed capacity in 2009 was around 1372MW [6], this is 61% more as compared to renewable power generation installed capacity in 2005. Table I shows the details of renewable power generation installed capacity (IC) and Table II shows the actual renewable generation in Victoria [5, 6].

TABLE I. VICTORIA RENEWABLE POWER GENERATION IC

YEAR	2000	2005	2009	2010	2011	2012
MW	668	847	1372	1429	1633	1869

TABLE II. VICTORIA ACTUAL RENEWAL POWER GENERATION

YEAR	2010	2011	2012
GWH	2632	2931	3825

The percentage of Victoria's electricity contribution from renewable power generation was 7.7% in 2012 as compared to 5.5% in 2011 [2, 5]. The average electrical energy consumption for the year 2012 was around 199.3 TWH with an average load demand of 22751.4 MW and the state of Victoria accounted for 26% of the total energy consumption, i.e., 50.37 TWH [3]. As stated earlier, the total electrical energy consumption has been forecasted at 225 TWH in the year 2020; assuming the consumption for Victoria in 2020 to be at 26% and hence, it can be forecasted at 58.5TWH which gives a target of 11.7 TWH to be generated from renewable energy sources to achieve the 20% RET. The renewable energy generation in Victoria as of 2012 stands at 3825 GWH [5] as shown in table II, an additional LRET of 7875 GWH is required to achieve the 2020 RET for Victoria.

III. AVAILABILITY OF WIND AND SOLAR IN VICTORIA

This section presents the details of solar and wind resources availability in Victoria [4].

A. *Solar energy*

Solar energy is clean, eco-friendly environment and does not contribute greenhouse gas. Solar radiation is converted into electrical and thermal energy by means of solar photovoltaic and solar water heater. Concentrated solar power technology converts solar thermal power into useful electrical energy. Solar power is an intermittent and not reliable. Solar power is dependent on solar insolation. Solar insolation is the amount of solar radiation at given time.

$$\text{Solar Insolation (E)} = \text{Wh/m}^2\text{/day} \quad (1)$$

$$\text{Solar cell efficiency} = P_{mp}/(E*(A))\ m^2 \quad (2)$$

(where P_{mp} is maximum power, A is area)

The below Figure 1 shows the solar exposure details in Victoria. The Victoria has good solar resources, especially in Mildura which receives 90% of Brisbane solar exposure level [4]. Victoria annual average global solar exposure on horizontal surface is in the range of between 12 to 20 mega joules per square meter per day (MJ/m^2/day) [4].With reference to Victoria state Latitude and Longitude co-ordinates, the monthly average solar exposure data was collected from NASA surface meteorology and solar energy website [7]. The monthly average solar exposure is around 4.30kwh/m^2/d [7].

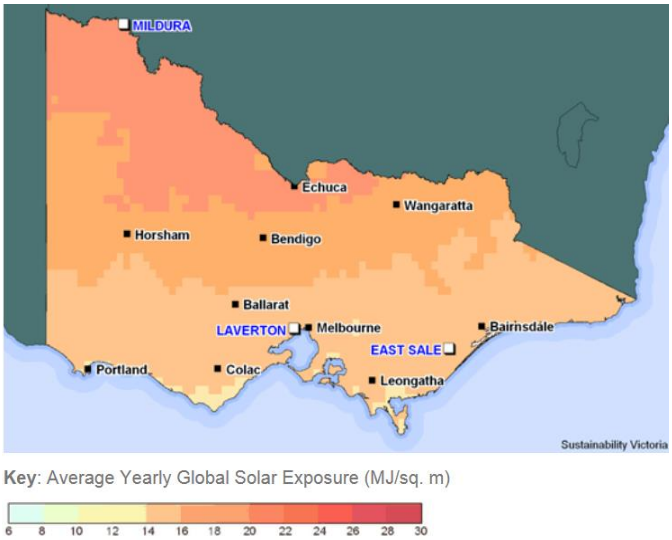


Figure 1: Average annual solar exposure of Victoria

B. *Wind energy*

Wind energy is clean, non-polluting and does not contribute any greenhouse gas emissions. According to global wind energy council (GWEC) 12% of global energy will be supplied by wind energy in 2020 [8]. Wind power is an intermittent and highly variable. Wind power generation is dependent on wind speed.

$$\text{Wind power } (W_p) = C_p*1/2\text{þ}av^3 \quad (3)$$

(where (þ) is air density (1.225kg/m^3), (v) is the wind velocity in (m/sec), (a) is rotor swept area in m^2 and (C_p) is the wind power co-efficient).

Good amount of wind source is available in Victoria State. The below Figure 2 shows, there are several areas of the state having average wind speed of around 6.5m/sec [4]. With reference to Victoria state Latitude and Longitude co-ordinates, the monthly average wind speed data was collected from NASA surface meteorology and solar energy website [7]. The monthly average wind speed is around 5.83m/sec [7].

The next section describes a hybrid solar and wind power system for large renewable power generation.

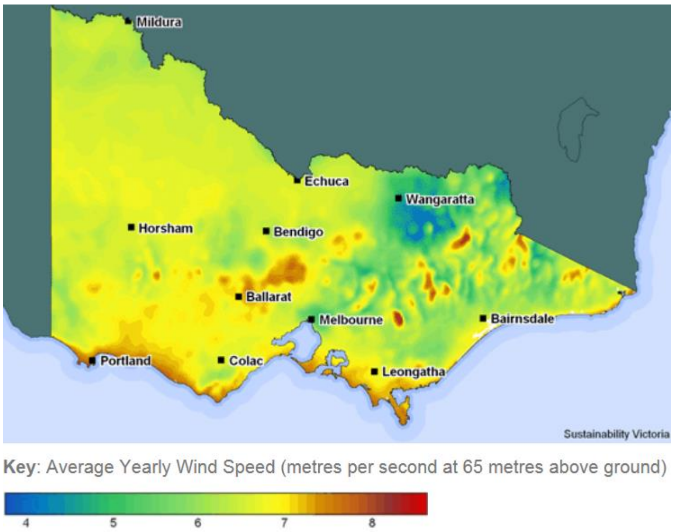


Figure 2: average annual wind speed level at 65mt.

IV. HYBRID POWER SYSTEM

Solar and wind power sources with typical average load of 67.5kw (1621kwh/day) connected to a grid is modeled in HOMER for simulation. By using HOMER software, optimal study and sensitivity analysis has been carried out in economic, environmental point of view.

A. *Economic factors*

The net present cost (NPC) and cost of energy (COE) of solar and wind power generation has been analyzed in optimum level. Below equation shows the formula of economic factors [9, 10].

$$\text{NPC (\$)} = \text{TAC} \div \text{CRF} \quad (4)$$

$$\text{CRF (\$)} = i(1+i)^N \div (1+i)^N\text{-}1 \quad (5)$$

(where TAC is total annual cost, CRF is capital recovery factor, N is number of years and (i) is annual interest rate).

$$COE\ (\$) = C_{ann.Total} \div E \quad (6)$$

(where $C_{ann.Total}$ is annual total cost and E is in kwh)[10, 11].

B. Renewable fraction (RF)

RF is the fraction of renewable energy contribution from RE power sources in hybrid power system. Solar PV fraction f PV and wind fraction *f* WT are given by below equation.

$$f\ PV = E_{PV} / E_{ann.Total} \quad (7)$$

$$f\ WT = E_{WT} / E_{ann.Total} \quad (8)$$

(where E_{PV} , E_{WT} are PV and Wind power generation and $E_{ann.Total}$ is annual total energy generation).

C. Emission factors

Emission is related to greenhouse gases (GHG); CO_2, SO_2, NO_x, causes atmospheric pollution. GHG emission is expressed in annual basis (kg/year) and also measured in terms of per capita (kg/kwh). Around 28 billion tons of CO_2 gets injected in global level from burning of fossil fuels in every year [12].

D. Modeling of Hybrid power system in HOMER

In this paper, grid connected solar and wind power hybrid system is considered without any energy storage system. Figure 3 shows the modeling layout of grid connected HPS with solar, wind power sources, converter and typical load of 67.5kW.

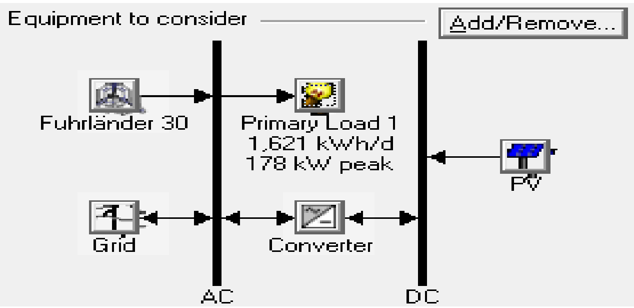


Figure 3: HPS module in HOMER code

(i) Electrical load

In this HPS module, typical part load (1621kwh/d) of Victoria State is considered for simulation purpose. Figure 4 shows details of monthly average load profile.

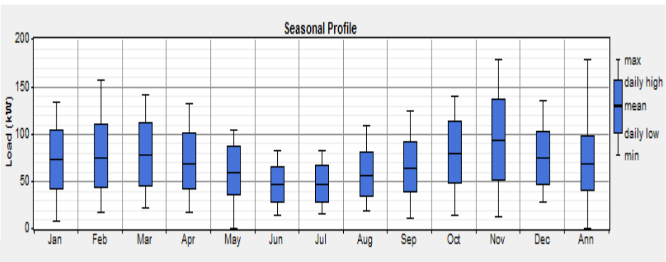


Figure 4: Typical monthly average load profile

(ii) Solar Source

The data of monthly average solar insolation incident on horizontal surface was collected from NASA surface meteorology and solar surface web site [7] with respect to Victoria coordinates. Figure 5 shows the monthly average solar exposure levels with clearness index (CI).

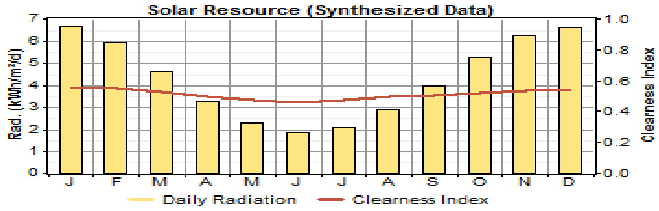


Figure 5: Monthly average solar exposure levels

(iii) Details of Solar Photovoltaic (PV) module

Solar PV module is more expensive in HPS and for simulation purpose 1Kw PV module is considered with capital cost around $4000, replacement cost $3200. Figure 6 shows the details of PV system.

PV

Size (kW)	Capital ($)	Replacement ($)	O&M ($/yr)
1.000	4,000	3,200	0

Sizes to consider:	0, 7, 10, 20, 50, 100, 150, 200, 300 kW
Lifetime:	20 yr
Derating factor:	80%
Tracking system:	No Tracking
Slope:	38.3 deg
Azimuth:	180 deg
Ground reflectance:	20%

Figure 6: Details of PV system

(iv) Wind source

The monthly average wind speed data measured at 50 meter elevation was collected from NASA surface meteorology and solar energy [7], with respect to Victoria co-ordinates. Figure 7 shows the graphical representation of wind speed level.

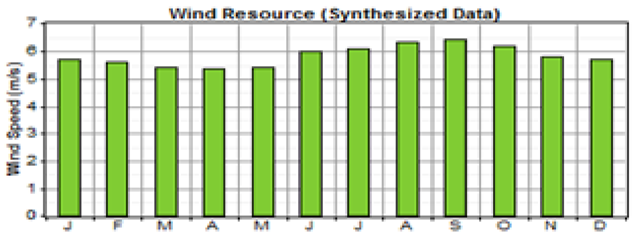


Figure 7: Monthly average wind speed

(v) Details of Wind turbine

The Funhrlander-30 wind turbine (AC 30kw) is considered for simulation purpose with capital cost $27500, replacement cost $25000, operation cum maintenance cost of $550. Figure 8 shows the details of wind turbine power curve.

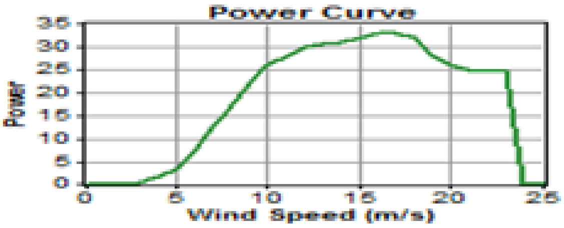


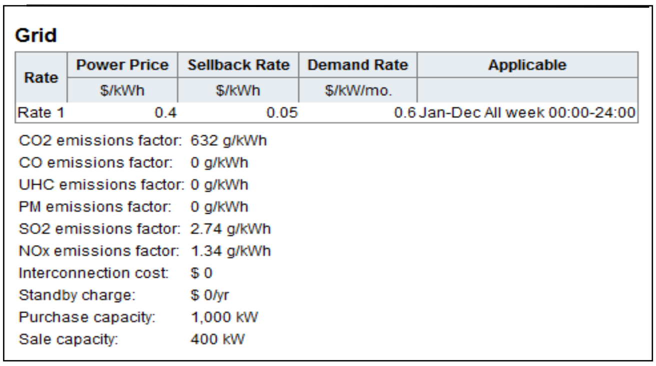
Figure 8: Wind turbine power curve

(vi) Power Converter

Power converter of 1KW is used as inverter as well as rectifier or both. In this module, it is used to convert DC into AC (inverter).

(vii) Grid component

In HPS module, grid plays an important role as backup power source to connected loads, during the lack of solar and wind power source generation. Figure 9 shows the details of standard grid component.



Grid

Rate	Power Price $/kWh	Sellback Rate $/kWh	Demand Rate $/kW/mo.	Applicable
Rate 1	0.4	0.05	0.6	Jan-Dec All week 00:00-24:00

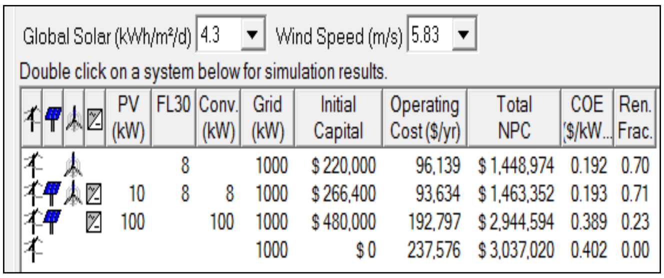
CO2 emissions factor:	632 g/kWh
CO emissions factor:	0 g/kWh
UHC emissions factor:	0 g/kWh
PM emissions factor:	0 g/kWh
SO2 emissions factor:	2.74 g/kWh
NOx emissions factor:	1.34 g/kWh
Interconnection cost:	$ 0
Standby charge:	$ 0/yr
Purchase capacity:	1,000 kW
Sale capacity:	400 kW

Figure 9: Grid component details

V. RESULTS ANALYSIS

A. Optimization Analysis

By HOMER simulation, the optimum level of economic (NPC, COE) and environment factors (CO_2, SO_2, NO_x emissions) are identified. With reference to grid tariff ($0.4/kwh) normal and ($0.6/kwh) peak rates, the various combination and fraction of renewable source generation at average solar exposure 4.30 kwh/m^2/day, average wind speed 5.83 m/sec are considered [7]. Figure 10 shows the HPS module of simulated configuration.



Global Solar (kWh/m²/d) 4.3 Wind Speed (m/s) 5.83

Double click on a system below for simulation results.

	PV (kW)	FL30	Conv. (kW)	Grid (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.
		8		1000	$ 220,000	96,139	$ 1,448,974	0.192	0.70
	10	8	8	1000	$ 266,400	93,634	$ 1,463,352	0.193	0.71
	100		100	1000	$ 480,000	192,797	$ 2,944,594	0.389	0.23
				1000	$ 0	237,576	$ 3,037,020	0.402	0.00

Figure 10: Optimization results with 4.3 kWh/m^2/d solar radiation and 5.83 m/s wind speed.

TABLE III. OPTIMIZED RESULTS OF ECONOMIC AND ENVIRONMENT FACTORS.

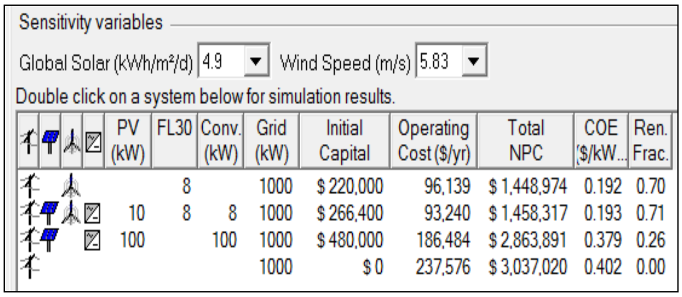
HPS	NPC ($)	COE ($/kwh)	RF (%)
Wind-grid	1448974	0.192	70
Wind-pv-grid	1463352	0.193	71
Pv-grid	2944594	0.389	23
Grid	3037020	0.402	0
Emissions	**Co2 (kg/year)**	**So2 (kg/year)**	**Nox (kg/year)**
Wind-grid	-36798	-160	-78
Wind-pv-grid	-44649	-194	-94.7
Pv-grid	295315	1280	626
Grid	373932	1621	793

Homer simulation with given grid electricity price (0.4$), average wind speed (5.83 m/sec), solar exposure (4.30 kWh/m^2/d) of Victoria state, the optimization results are detailed below.

From Table III; it is clearly shows that wind-grid and wind-PV grid systems are more economical than PV-grid and standard-grid system. Similarly wind-grid and wind-PV-grid system emission levels are lower than PV-grid and standard grid system.

B. Sensitivity analysis

Sensitivity analysis carried out with various values of solar exposure (4.5,4.6,4.7,4.8,4.9) and wind speed (5.9,6.1,6.3,6.4,6.5). The emissions, NPC, COE and renewable fraction are simulated based on the above said sensitive variables. Figure 11 shows the details of HPS model with sensitivity simulation.



Sensitivity variables

Global Solar (kWh/m²/d) 4.9 Wind Speed (m/s) 5.83

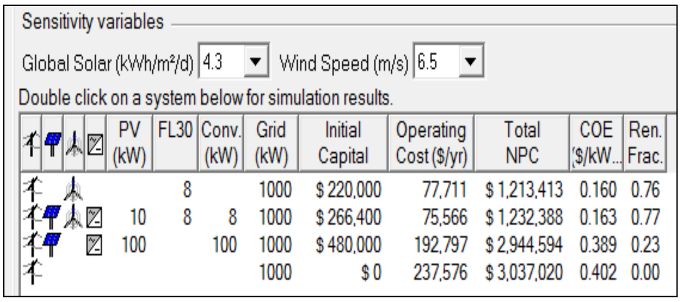
Double click on a system below for simulation results.

	PV (kW)	FL30	Conv. (kW)	Grid (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kW...	Ren. Frac.
		8		1000	$ 220,000	96,139	$ 1,448,974	0.192	0.70
	10	8	8	1000	$ 266,400	93,240	$ 1,458,317	0.193	0.71
	100		100	1000	$ 480,000	186,484	$ 2,863,891	0.379	0.26
				1000	$ 0	237,576	$ 3,037,020	0.402	0.00

Figure 11: Sensitivity analysis (with maximum solar sensitive value)

From the above results, with maximum solar exposure sensitive value (4.9 kwh/m^2/d), average wind speed (5.83 m/sec), it is clearly shows that, there is no significant changes in NPC, COE and RF value for wind-grid and wind-PV-grid system. Only in PV-grid system, the NPC come down around 2.7% (from $2944594 to $2863891), COE come down from 0.389 to 0.379$/kwh and RF percentage increases from 23 to 26%. Also 4% reduction of CO_2 (from 295315 kg/year to

283304 kg/year), SO_2 (from 1280kg/year to 1228 kg/year) and NO_x (from 626 kg/year to 601 kg/year) emission level. Figure 12 shows the details of sensitivity analysis and Table IV shows the optimized results of economic and environment factors.



PV (kW)	FL30	Conv. (kW)	Grid (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kW...	Ren. Frac.
	8		1000	$ 220,000	77,711	$ 1,213,413	0.160	0.76
10	8	8	1000	$ 266,400	75,566	$ 1,232,388	0.163	0.77
100		100	1000	$ 480,000	192,797	$ 2,944,594	0.389	0.23
			1000	$ 0	237,576	$ 3,037,020	0.402	0.00

Figure 12 : sensitive analysis (with maximum wind speed sensitive value)

TABLE IV. OPTIMIZED RESULTS OF ECONOMIC AND ENVIRONMENT FACTORS

HPS	**NPC ($)**	**COE ($/kwh)**	**RF (%)**
Wind-grid	1213413	0.160	76
Wind-pv-grid	1232388	0.163	77
Pv-grid	2944594	0.389	23
Grid	3037020	0.402	0
Emissions	**Co2 (kg/year)**	**So2 (kg/year)**	**Nox (kg/year)**
Wind-grid	-117523	-510	-249
Wind-pv-grid	-125374	-544	-266
Pv-grid	295315	1280	626
Grid	373932	1621	793

From the above results, with maximum sensitive value of wind speed (6.5m/sec), average value of solar exposure (4.30kwh/m^2/d), wind-grid system NPC value come down 16.26% (from $1448974 to $1213413) and COE value come down from $0.192 to 0.160; similarly the wind-PV grid system NPC value come down 15.49% (from $1458317 to $1232388) and COE value come down from $0.193 to $0.163/kwh. Wind-grid system CO_2 (from -36798 to -117523kg/year), SO_2 (from -160 to -510 kg/year) and NO_x emissions (from -78 to -249 kg/year) level come down around 3.19 times; Similarly for wind-PV-grid system around 2.8 times of CO_2 (down from -44649 to -125374kg/year),SO_2 (down from -194 to – 544 kg/year) and NO_x (from -94.7 to -266kg/year) emissions are come down.

From the above sensitivity analysis, with increased wind speed from 5.83 to 6.5m/sec, wind power combination grid system, that is wind- grid and wind-PV-grid systems are more efficient than PV-grid and standard grid system.

VI. INTEGRATING CHALLENGES OF RENEWABLE ENERGY SOURCES

Renewable energy sources; solar and wind power generation is highly variable and intermittent. The major challenges of integrating renewable generation into utility grid are as follows [13-15].

(i) Grid stability and reliability

(ii) Power quality (PQ); voltage fluctuation, power system transients, electromagnetic interference, harmonic distortion, low power factor and reactive power compensation.

(iii) High cycling rate (ramp up/ramp down) of conventional power plant, causes more maintenance cost and less life time of equipment.

(iv) Additional spinning reserve capacity of conventional power plant (peaking plant), development of transmission and distribution infrastructures, increases cost of investment.

A. Key solutions for integrating challenges

(i) Plan according to forecast and seasonal load demand : According to predicted forecast weather for wind and solar, seasonal load demand; the backup (reserve) conventional power plants can be planned to switch on , switch off or ramp up, ramp down by utility to maintain stability and integrity of grid. However, the forecast plan is not accurate all the time. This will make additional investment cost and also high maintenance cost, less life time of conventional power plant equipment due to cycling effect [15].

(ii) National or regional grid level power sharing : With better co-ordination between National and regional level, the availability of excessive generation in one region can be shared with deficit region through long transmission lines. This will make additional transmission line infrastructure cost and also increase line losses [15].

(iii) Custom power Devices (CPD) : There are various power conditioning devices with power electronics technology; Static synchronous compensator (STATCOM), Dynamic voltage regulator (DVR), Unique power quality conditioner (UPQC) can be used to mitigate power quality issues [16, 17].

(a) STATCOM : It is a shunt connected CPD provides power factor correction, harmonic current filtering, load balancing with better voltage regulation in distribution network. STATCOM with combination of voltage and current PWM converter technology compensates the harmonic current injection and poor power factor at load side [16, 17].

(b) DVR : Series connected CPD protects the sensitive loads from supply side disturbances. It act as series active filter provides positive isolation to power source from harmonics injected by load. DVR with voltage source PWM converter maintains required amplitude and wave form of load side voltage profile even there is disturbance in source side voltage disturbance [16, 17].

(c) UPQC : It is a combination of series and shunt active filter connected in back to back configuration. The series component of UPQC mitigates supply side disturbances; voltage sag or swell, voltage unbalance, harmonics. The shunt component mitigates current quality issues caused by consumer end ; poor power factor, harmonic currents, unbalance from load side [16, 17].

(iv) Energy Storage system (ESS) : The ESS is one of the best option to reduce impacts of integrating renewable generation

into main grid. It has ability to smooth out variations of renewable power generation with following additional features [15, 18].

(a) Load leveling
(b) Peak shaving
(c) Improves grid stability
(d) Helps in reduction of greenhouse gas emissions
(e) Improves power quality
(f) Better energy and power management

VII. CONCLUSION

The HPS model is configured with grid connected typical load of 67.5kw (1621kwh/day), with 30kw AC funhrlander-30 wind turbine, 1kw solar PV module and 1kw power converter. From the above HPS model simulation, at average solar exposure of 4.30 kwh/m^2/day and wind speed of 5.83 m/sec can get an optimum level of COE $0.192/kwh, NPC $1448974, reduction of emission in CO2 -36798 kg/year , SO2 -160kg/year, NOx -78kg/year for wind - grid system and COE $0.193/kwh, NPC $1458317, reduction of emission of CO_2 -44649kg/year, SO_2 -194kg/year , NOx -94.7kg/year for wind-PV-grid system. From the sensitivity analysis with increase in wind speed from 5.83m/sec to 6.5 m/sec, COE 16.67%, NPC 16.26% come down and also 3.19 times reduction of emission level for wind-grid system. Similarly for wind-PV-grid system; COE 15.55%, NPC 15.49% come down and 2.8 times reduction of emission level. From the above results, it is concluded that wind power combination renewable generation in Victoria is more feasible in economical and environment of view; because of abundant wind source in Victoria than Solar.

This paper presents the basic study in the following manner.
(i) study related to RET for Victoria in 2020
(ii) feasibility study of solar and wind power generation in Victoria
(iii) study related to challenges and available key solutions of integrating renewable energy sources to the grid.
In addition to the above points of study, further thorough research and investigation is required in the following directions.
(i) further feasible study and deep investigation is required in high level to develop efficient renewable generation in Victoria
(ii) further study and deep analysis required against existing integrate challenges of renewable energy sources into modern power grid.

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