Volume 8, Issue 5
October 2019

ITEE Journal
Information Technology & Electrical Engineering

ISSN: - 2306-708X

Optimal Deployment of Renewable Energy Sources with Grid Integration

[1] Vilas S. Bugade and [2] Pradeep K. Katti
[1]Research Scholar, Department of Electrical Engineering,
Dr. Babasaheb Ambedkar Technological University, Lonere, Raigad, Maharashtra, India.
[2]Professor, Department of Electrical Engineering,
Dr. Babasaheb Ambedkar Technological University, Lonere, Raigad, Maharashtra, India.
E-mail: [1]punamvilas12@gmail.com, [2]pkkatti@dbatu.ac.in

ABSTRACT

The recent developments in electrical power system are enormously on demand side management for grid integration with compound renewable energy sources (RES). At a transitory look synchronization up- gradation predominantly focuses on the different parameters of electrical systems. This paper presents the testing and exploration of fabricated three phase inverter of 10 kW for multiple sources of energy like solar PV, wind energy, battery and diesel generator for three phase grid integration. It is in consideration with an optimal power flow assessment of these sources. The real time monitoring, controlling and protection is provided through digital signal processor (DSP) and protective switchgears. The constraints are lively for coordinating of voltage, frequency and oscillations at the point of common coupling (PCC) during grid integration with RES. Also, these are advantageous for the switching of protective devices through remote monitoring and control. To conclude, with these features testing is accomplished for linear, nonlinear and dynamic loading. These results are proximate to the specified tolerance at different universal moral.

Keywords: *Digital Signal Processor, Hall-effect Sensors, Insulated Gate Bipolar Transistor, Solar PV, Wind Energy*

1. BASIC

The electricity distribution systems are experiencing a major amendment due to the inclusion of demand side smart appliances loads and non-conventional distributed generation (DG) units. These programmable dependable smart appliances loads have the capability to control their real power consumption [1][4]. Disparately, the power electronics devices like inverters used for interfacing of solar photovoltaic (PV), wind energy, fuel cells etc., with the existing grid can harvest or place away reactive power, affect to fine percentage voltage regulation across the distribution feeders [2]. Therefore, it is needed to deals with distributed management of apparent power (including active and reactive power) in supply systems leading a large number of programmable loads and DG units, distributed across the feeders [2][3]. Stochastic user interface design tools are established to cope with the fundamental RES improbability. So that an optimal control of reactive power that is adaptive to the RES generation need to be incorporated [5][6]. The prominent challenges in power (real and reactive) management is that the power flow equations need to be multifaceted in nature, for the complete form of power flow equations in radial distribution systems [3][7]. In recent years, rounded estimates or moderations have followed to render the significant optimization difficulties [8]. The centralized reactive power management problem are depends on a direct estimate of the power flow contrasts in radial networks [8][9]. In this paper it is presented a framework for real and reactive power management in distribution systems under uncertainty of RES power generation, which adopt deterministic optimization models. The complete tactic is spreads to a stochastic programming model; however decision making happens in two stages. These verdicts are the real power consumption of programmable loads and the reactive power generated or consumed by the

RES inverters [10][12]. The proposition is that the inverter reactive power decided by an elegance of adaptive to the real power generated by the RES units and same demonstrated as an arbitrary by compelling values from a set of possible set-ups [11][13].

The monitoring, control and protection of the smart grid are probable to be considered by the strictures of communications strategies used at generation and demand Side [14]. Distributed monitoring and control has typical features of generation resources and involvement of loads in the energy management, also need for fast and local reactivity for dynamic control and protection [15]. From the innovative technology of the convenient energy sources and through the regular variability of some RES, the compassion to individual load disparity is greater than in traditional systems. Effective and conservation fascinated energy management for modern development of the building sectors which contributes the large portion of electricity consumption and greenhouse gas emission [16]. For smart microgrid and RES integration it has provided an opportunity to improve the building energy efficiency, minimize energy cost, and reduce the greenhouse emission. In precise, instigated fabricated device should be tested in the convolution of the environment in which they will operate. The focus in this work is particularly on integrating RES with the communication aspects in monitoring and control. The hardware and component design are not exempt by the same complications of designing, validating and testing control algorithms without losing essential dynamic behaviors [17].

The smartgrid is the combination of energy transmission engineering and advanced information technology. It is

ITEE Journal
Information Technology & Electrical Engineering
ISSN: - 2306-708X

expected to be a powerful solution for societies pursuing high efficiency with uninterrupted power [18][19]. This paper presents concerns for power and energy, based on a distributed control model of energy systems. RES taken into consideration and a 10 kW grid tied three phase module is designed and fabricated. The perception is instigated for system setup for optimal power flow with monitoring, control and protection, which acts as a smart grid, Fig. 1 gives thought process for of research for power flow. The conception is herewith proposes interface of developed device as smart-inverters. The communication device realizes effective system around both an information network and an energy network for distributed energy control for the exploration of power flow. Testing and discussions are described in detailed with results of diversified loads and conclusion on ultimate results.

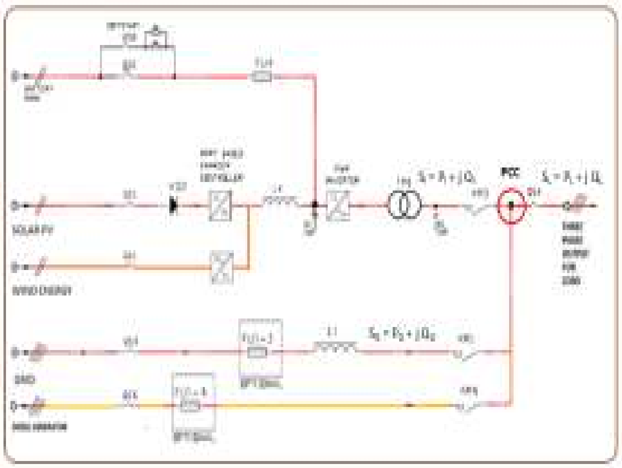

Fig.1.Sources of energy of RES, Battery, DG and existing grid for grid integration

2. MATERIAL AND METHODS

2.1 Exploration of Power Flow

The modern developments of grid integration are emphases on optimal power flow exploration for distributed energy sources. The grid integration facets in the control design process for smartgrid uses requires the development of theoretical procedures persistent from the conventionally approved control devices [20][21]. Each exploration of power flow is with view of considering single RES and utility available at that node.

In view of distributed generation there may be multiple sources of energy generation as shown in figure1. The power flow exploration with optimal way is represented in such complicated power system [9]. Even it is necessary to implement such topology in the commercial and industrial demand side management as a distributed system. Therefore, in this paper the comprehensive concept is summarized by fabricating such a device which will scatter the demand side as an uninterrupted. For which the hardware is designed, developed and fabricated for performing the desired task of 10 KW demand.

2.2 Major Components of Three Phase Inverter

It mainly consists of a DSP, IGBT, Hall-effect (HE) sensor, temperature sensor, D.C. capacitors, RES Input Capacitor and Display. Using these components the device is developed and installed for supplying electricity at educational institute premises. The three phase inverter is mainly supplied with multiple input energy sources of RES as Solar PV (5 KW, 170 V D.C.), Wind Energy (Induction generator 2.5 KW, 230 V, 50 Hz, Single Phase), three phase existing grid (440 V, 50 Hz), Battery (12 V, 10 AH – 10 Nos.) and Diesel Generator (100 kVA, 440 V, 50 Hz).

The RES output is hardened for D. C. and given to common D.C. bus of 120 V. For same bus the battery conditioned D.C. is integrated. Further from the common D.C. bus IGBT (SKM195GB066D-200A/600V, SEMIKRON makes) bridge circuit has converted it into three phases pulsating output of 130 V. Then 10 kVA, 130V / 415 V, 50 Hz three phase delta / Star connected transformer converts it into three phase A.C. which is given to demand side utility.

2.3 Metering Data for Exploration

To implement the proposed system an apparent power equations at the derived output of system sources as shown in the Fig.1, as apparent power SI, SG, SL for RES inverter output, existing grid and demand side loads respectively (the diesel generator unit is a standby device) for fulfilling load side unhampered. This is an appropriate technique for the device for making decisions at PCC in opinion of coordinating the system parameters. The functional block consists of all the statistical blocks based on power flow strategies which concert of demand side management.

Fig.2.RES metering system while furnishing loads

The synchronizing of voltage, frequency and waveform at PCC for all output Powers as SI (t), grid power as the SG (t) and PB (t) as battery power for polyphase networks are the measure and tract of DSP at each output sensing through hall-effect sensors. These sensors give the real time feedback to the processor for monitoring and control of power flow, in view of phase sequence and phase displacement. The concerned part of the DSP is from the attenuator device which generates pulse width modulation (PWM) as per prerequisite for matching the parameters at PCC. CANBUS is the parallel port which receives signal from the DSP board for display and mimic unit for protection and alert alarms. User interface communication device interacts through ETHERNET having potential free contact forwards the various inputs like emergency power OFF, Solar irradiation, wind velocity, battery temperature and D.C. earth fault etc. on display unit. It simplifies the significance of demand side management with RES as a primary source of network [9]. The multiple RES D.C. output is given as input to the IGBT hex-bridge module, which delivers voltages (line / phase) and currents to the network [23].

2.4 **Optimal Power Extractions of Grid Interconnection Networks**

The supplied voltages (VAN, VBN, VCN, VAB, VBC, VCA) and currents (iA) level is given by equations (1) – (7) for 1800 conduction (R-L load) or can be modified for 1200 conduction with other nature of the loads [24].

$$V_{AN} = \sum_{n=1}^{\infty} \frac{4\ Vs}{\sqrt{3}n\pi} \sin\left(\frac{n\pi}{3}\right) \sin(n\omega t) \ \ \text{Volt} \qquad (1)$$

$$V_{BN} = \sum_{n=1}^{\infty} \frac{4\ Vs}{\sqrt{3}n\pi} \sin\left(\frac{n\pi}{3}\right) \sin\left(n\left(\omega t - \frac{2\pi}{3}\right)\right) \ \ \text{Volt} \quad (2)$$

$$V_{CN} = \sum_{n=1}^{\infty} \frac{4\ Vs}{\sqrt{3}n\pi} \sin\left(\frac{n\pi}{3}\right) \sin\left(n\left(\omega t - \frac{4\pi}{3}\right)\right) \ \ \text{Volt} \quad (3)$$

Line voltages,

$$V_{AB} = \sum_{n=1}^{\infty} \frac{4\ Vs}{n\pi} \sin\left(\frac{n\pi}{3}\right) \sin\left(n\left(\omega t + \frac{\pi}{6}\right)\right) \ \ \text{volt} \quad (4)$$

$$V_{BC} = \sum_{n=1}^{\infty} \frac{4\ Vs}{n\pi} \sin\left(\frac{n\pi}{3}\right) \sin\left(n\left(\omega t - \frac{\pi}{2}\right)\right) \ \ \text{Volt} \quad (5)$$

$$V_{CA} = \sum_{n=1}^{\infty} \frac{4\ Vs}{n\pi} \sin\left(\frac{n\pi}{3}\right) \sin\left(n\left(\omega t - \frac{7\pi}{6}\right)\right) \ \ \text{Volt} \quad (6)$$

$$i_A = \sum_{n=1}^{\infty} \left[\frac{4\ Vs}{\sqrt{3}(n\pi\sqrt{R^2 + (n\omega L)^2}\ )} \sin\frac{n\pi}{3}\right)] \sin(n\omega t - \theta_n) \quad (7)$$

Where $Vs - \text{d.c. input voltage in volt (RES)}, n = 1,3,5$

These equations give us the output parameters (voltages and currents) of multiple RES, which are useful for synchronizing voltages at PCC while grid integration in terms on magnitude and angle.

Requisite of realization for higher dynamic abilities is also inspiring the traditional consolidated control architecture. Therefore it is necessary to treasure the right balance between centralized, distributed and delocalized control is one of the most stimulating theoretical challenges for the development of the imminent smart grid. The maximum voltage (Vm) and current (Im) are formulated as,

$$V_m = \frac{2V_{RN}}{3} \ \ \text{volt} \ \ \text{and}$$

$$I_m = \frac{2V_{RY}}{3\ R} \ \ \text{Amp. (for resistive load)} \qquad (8)$$

It is possible to create an optimal flow from equation (7) of based on first order transfer functions for active (Pi) and reactive (Qi) power of the inverter as equations (9) and (10).

$$\frac{dP_i}{dt} = \frac{P_{max}}{\tau_p}\left(U_p - \frac{P_i}{P_{max}}\right) \qquad (9)$$

$$\frac{dQ_i}{dt} = \frac{Q_{max}}{\tau_q}\left(U_q - \frac{Q_i}{Q_{max}}\right) \qquad (10)$$

Where Up, Uq output indication from inverter and Ꚍp, Ꚍq is time constant for active and reactive power, Pmax, Qmax maximum output of inverter respectively in equations (9) and (10).

Then for electrical storage devices,

$$\frac{dP_b}{dt} = \frac{P_{maxb}}{\tau_b}\left(U_b - \frac{P_b}{P_{max}}\right) \qquad (11)$$

$$\frac{d_{soc}}{dt} = b.P_b \qquad (12)$$

Ub is the signal for generated power of battery and Pmaxb is the maximum output power of battery in equations (11) and (12).

It is necessary to recognize the output voltage at respective nodes, which are contingent of frequency and current. It will be the cause for the variation in the frequency as shown in equation (13) i.e. difference between on P_L (t)Connected and P (t) Generated

$$\frac{d\omega}{dt} = \lambda\left(P_{(t)Generated} - P_{(t)Connected}\right) + (\omega_{max} - \alpha P - \omega) \quad (13)$$

In islanded distributed generation it is important to uphold the frequency and voltage regulation. This is for control the frequency and voltage in a proper effective way and given in equation (14).

$$J = \int_{t_0}^{t_f} (\xi_\omega |\omega - \omega_{ref}|^2 + \xi_V |V_t - V_{ref}|^2) dt \qquad (14)$$

These equations are beneficial for maintaining the voltage and frequency around their reference values. This will be achieved by adjusting (ξ_ω, ξ_V) the frequency and voltage regulation could be changed by providing such facility in the controller.

From Fig. 2 and Fig. 3 metering there is has direct access of RES and exiting grid parameters data while the fulfillment of loads. It is possible to get such analog metering system by interfacing designed device with software (VISIO). This can show individual source parameters of RES (Solar PV, Wind Energy, Fuel cells, etc.) as well as grid parameters which are useful for system monitoring while screening the data.

3. TESTING AND EXPLORATION

This section presents the performance assessment of the implemented device using DSP for power quality indices and some important results. The setup consists of TMS320F28335PGFA DSP, sensor circuit, signal conditioning circuit, a three phase variable linear and non-linear loads. The evaluation of DSP-based programming is

Volume 8, Issue 5
October 2019

ITEE Journal
Information Technology & Electrical Engineering

ISSN: - 2306-708X

confirmed on 'C' language on a PC have Intel Core processor of i3, 2.8 GHz, 64-bit and 2 GB RAM [27]. PWM method for three-phase inverters with three sine-waves phase shifted by 120° or 180° with the frequency of the preferred output voltage is compared with a very high frequency carrier triangle, the two signals are mixed in a comparator whose output is high when the sine wave is greater than the triangle and the comparator output is low when the sine wave or typically called the modulation signal is smaller than the triangle. In the present work PWM technique is used to control the switches of the inverter through hall-effect sensors. This is to digitize the power so that a sequence of voltage pulses can be generated by the ON and OFF the power contactors. The circuit consists of three phase IGBT inverter bridge having turn-on time of switch is 270 ns, turn-off time is 320 ns and switching frequency is 20 KHz. The complementary gate signals are delayed by a certain time to avoid simultaneous conduction of both switches in a leg. Delay between two complementary pulses should be more than 270+320=590 ns. Code generation is for combining the control logic and later generating the PWM signals, for smart meter technologies. The projected work have DSP programming for the controller and creating the microsoft-exel files used for extract real time data of device[25].

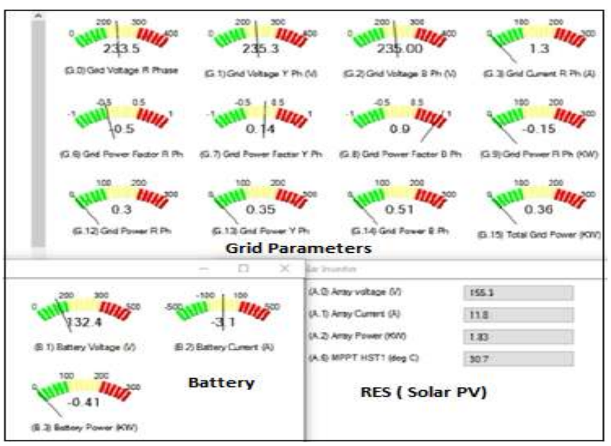

Fig.3. RES and existing grid metering while furnishing loads

3.1 Interface of Solar PV and Existing Grid

The switching action is monitored on the display unit and accessible at remote locations by using IP address insisted on the organism of Fig. 4 - Fig. 6.

The Table 1-Table 3 are self-explanatory that the instigated invention fulfills distribution network of electricity loads by the tactic of multiple RES by doing grid integration.

These devices has invited with protection anatomy for the distributed restrictions on display unit protection anatomy for the distributed restrictions on display unit for (a) Main menu window: parameter groups (b) Sub menu window: Grid parameters (c) Sub menu window: Inverter parameters (d) Sub menu window: RES parameters (e) Sub menu window: Statistics group (f) Sub menu window: Alarms (g) Sub menu window: Status. These parameters are useful for protecting the system or device from d. c. under / over voltage, output under / over voltage, over loads / temperature / current, grid abnormal, RES fail or grid fail etc. which is an inbuilt feature added in inverter [26].

Fig. 4 and Table 1 show scrutiny of Solar PV grid interconnection while fulfillment of load requirement and switching status of contactors by accepting signals from hall-effect sensors to the relays.

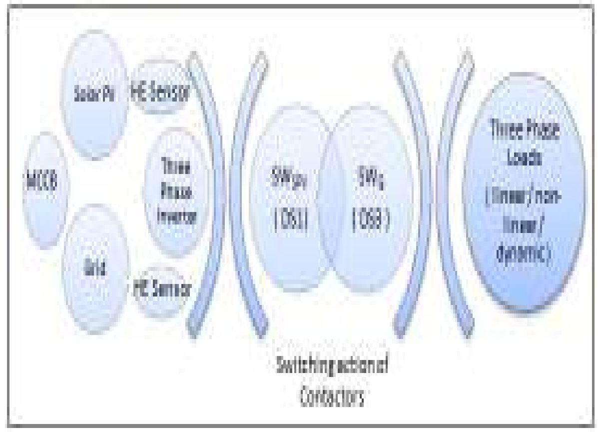

Fig. 4. Solar PV and grid

TABLE 1
ON/OFF status of Solar PV and grid

Sr. No.	Condition of Loads	Status of Switching		Remarks
		SW_{SPV}	SW_G	
1	$S_L = S_I$	ON	OFF	Only RES (Solar PV)
2	$S_L < S_I$	ON	ON	Only RES (Solar PV) and (S_I - S_L) supplied to grid as bidirectional flow.
3	$S_L > S_I$	ON	ON	Both RES (Solar PV) and grid

3.2 Interface of Wind Energy and Existing Grid

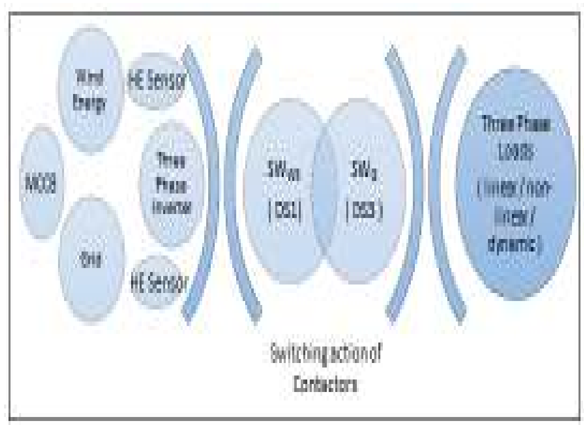

Fig. 5. Wind energy and grid

Volume 8, Issue 5
October 2019

ITEE Journal
Information Technology & Electrical Engineering

ISSN: - 2306-708X

TABLE 2
ON/OFF status of Wind Energy and grid

Sr. No.	Condition of Loads	Status of Switching		Remarks
		SW_{WE}	SW_G	
1	$S_L = S_I$	ON	OFF	Only RES (Wind Energy)
2	$S_L < S_I$	ON	ON	Only RES (Wind Energy) and ($S_I – S_L$) supplied to grid as bidirectional flow
3	$S_L > S_I$	ON	ON	Both RES (Wind Energy) and grid

Fig. 5 and Table 2 show scrutiny of Wind energy grid interconnection while fulfillment of load requirement and switching status of contactors by accepting signals from Hall Effect sensors to the relays.

3.3 Interface of Solar PV, Wind Energy and Existing Grid

Fig. 6 and Table 3 show scrutiny of Solar PV, Wind energy grid interconnection while fulfillment of load requirement and switching status of contactors by accepting signals from hall-effect sensors to the relays.

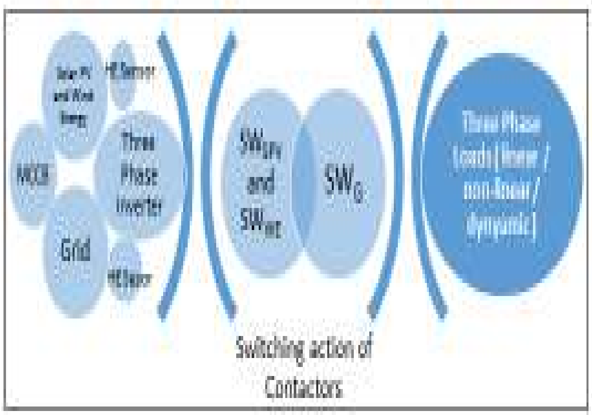

Fig. 6. Solar PV, Wind Energy and grid

TABLE 3
ON/OFF status of RES and grid

Sr. No.	Condition of Loads	Status of Switching		Remarks
		SW_{WE}	SW_G	
1	$S_L = S_I$	ON	OFF	Only RES (Solar PV and Wind Energy)
2	$S_L < S_I$	ON	ON	Only RES (Solar PV and Wind Energy) and (S_I - S_L) supplied to grid as bidirectional flow.
3	$S_L > S_I$	ON	ON	Both RES (Solar PV and Wind Energy) and grid

From exploration of RES grid interconnection, it gives that while supplying the electricity to load the surplus power is injected to grid as a bidirectional flow with uninterrupted operation.

4. RESULTS AND DISCUSSIONS

The testing is carried over a diversified load and situations. As the device has import / export data facility implanted in it for the different electrical parameters like current, voltage, active power in kW, reactive power in kVAR, apparent power kVA, power factor (cosϕ) and frequency etc. The Fig. 7 shows the active power sharing of multiple RES and grid. These parameters are accessible during normal operation with or without grid integration of individual / multiple RES. The main task in research is synchronizing a voltage, frequency and waveforms at PCC while grid integration of multiple RES.

Active power which is the dynamic grid support system has been implemented and it's working under a voltage drop incident has been verified. But whenever the reactive current is being injected into the grid, the active power fed needs to be proportionally throttled; else the total current might exceed the rated value of the plant which is practically not recommended. Hence another control block is included for throttling the active power in proportion to the increase in reactive power. This block will be activated whenever the reactive power control block is in operation.

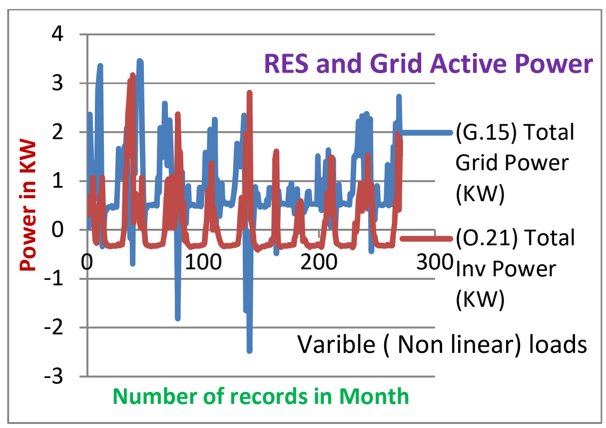

Fig.7. Active Power sharing between RES and Grid

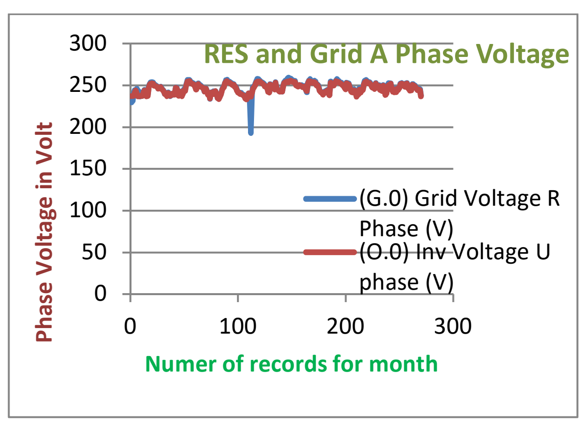

Fig.8. Voltage status of A phase at PCC for RES and Grid

Volume 8, Issue 5
October 2019

ITEE Journal
Information Technology & Electrical Engineering

ISSN: - 2306-708X

The Fig. 8, Fig. 9, Fig. 10 and Fig. 11 show that for voltages, frequency the specified limit is achieved as per IEEE1547-2018. Implementation of the dynamic grid upkeep scheme is created on the logic mentioned above a controller block is developed for a low voltage ride through (LVRT) and reactive power control. At the same time the MPPT controller is switched off. LVRT controller then checks for the grid voltage and time from the instant of fault occurrence and sends the trip signal for the circuit breaker. At the same time, whenever LVRT controller is active, the reactive power controller computes the amount of reactive current to be inoculated into the network based on the magnitude of the voltage drop. The logic has been provided in DSP programming. It is seen that the reference generated during the disconnect period is zero.

From the statistics at Fig. 8, Fig. 9 and Fig. 10, it shows that, the continuous consistency of RES and grid voltages for synchronizing at PCC for the duration of one month, which a tolerance of 0.04 % voltage regulation between multiple RES and grid voltages and which is acceptable deviation in grid integration practices.

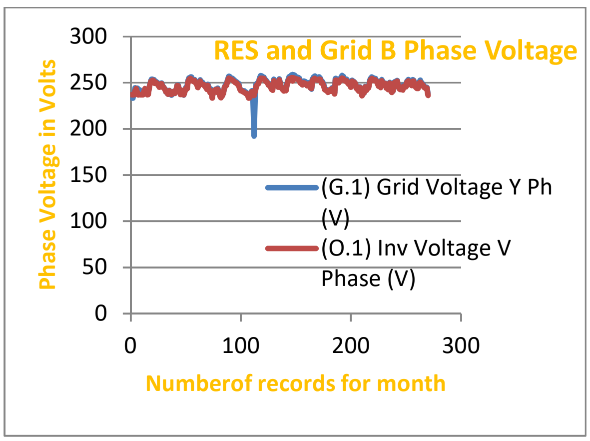

Fig. 9.Voltage status of B phase at PCC for RES and Grid

It will supportive for upcoming smart control centers, which are more anthropological, attentive for next generation monitoring utilities. It will provide the valuable uninterrupted information to machinists translating raw data in to useful format for defining desirable information. The huge volume of data can be transferred in to useful information. Therefore monitoring purposes may include cutting edge imagining techniques. which will help operators' to process information rapidly.

Also in Fig. 11 the frequency at the time synchronization has less variation, it constituency is very excellent. The frequency synchronizing of two or more a.c. sources is challenging task; the same is achieved in our system with desirable difference of 0.01 Hz consistently.

The research is beneficial for future generation online utilities and supportive for grid operators to decide wide range of operational boundaries in real time. The online monitoring of system parameters is morally built on contemporary operating conditions, does not effects on future system variations. If more or more renewable sources are integrated, power system will proficiency more uncertainties.[27] It will be give subsequent generation proactive online exploration and able to predict possible problems and optimize energy resources in a mode that demand response and energy storage is optimally balanced. It will help accomplish economic marks though improving grid reliability. The utilities would allow network operators to adopt a practical methodology to advance optimal directing schemes and mitigation tactics. Also coordinated protection and controlling strategies are developed to tackle sudden disturbances which may occur anytime in the power grid. It emphasized on major facts that, smart grid claims progressively need in the form of statistics gathering, communication abilities and data exploration techniques for solutions to exploit the data with artificial intelligence (AI). The ICT applications along the electricity circulation aspect have been presented with remotely monitoring of big data through IP address specified in the system [28].

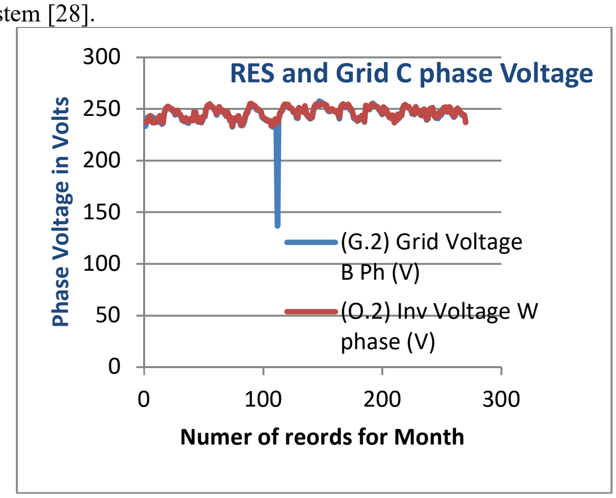

Fig.10. Voltage status of C phase at PCC for RES and Grid

It is also possible to monitor and control the power factor of inverter near to unity as shown in Fig. 12. The other parameters like KVAR, KVA, grid export / import power, battery charging / discharging status, DG utilization are recorded during the operation, which are useful for exploration of net generation and utilization status of individual / multiple sources of energy. The multiple RES device has been tested on the standard IEEE 1547-2018, test systems and a real time Indian Grid system on the rooftop of engineering institute. Reduction technique significantly reduced the number of variables and time required to solve optimal tracing problem. Earlier applying improved power flow tracing method, here we adopted progression power system network to find the reach sets of each load and energy supplied sources. A commercial optimization toolbox which failed to solve the large system like existing grid (India) without variable reduction, it solves the same system in 21.83 seconds with variable reduction technique.

It has been noticed that grid interconnection for the smart grid can be significantly improved by implementing cutting edge modern communication technologies in the form of advanced multifunctioning metering infrastructure, big data communication, improved Machine to Machine (M2M)

ITEE Journal
Information Technology & Electrical Engineering

ISSN: - 2306-708X

communication performances, Energy Management Systems, etc.[29] . Same is addressed in conclusion that smart grid built on the ICTs of detecting, communications, and governing technologies which will offers a promising future for utilities and end users.

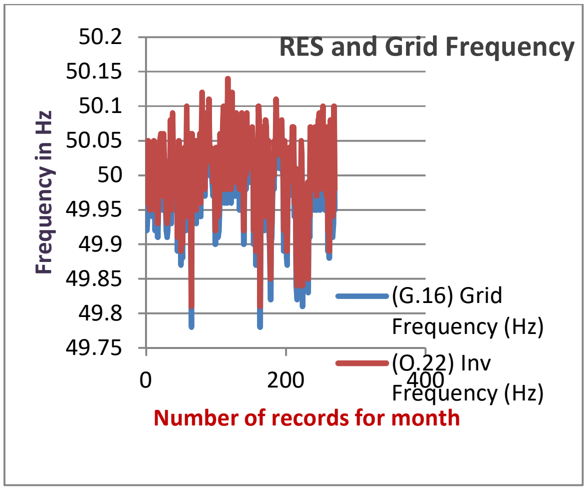

Fig.11.Frequency (India – 50 Hz) statuses at PCC For RES and Grid

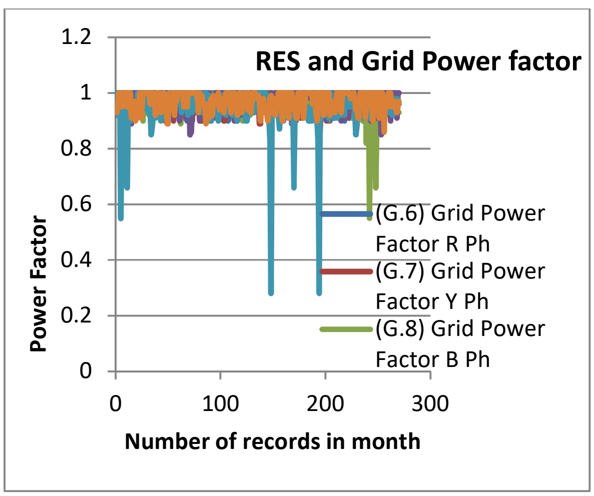

Fig.12. Power factor of Inverter and grid

5. CONCLUSION

In this research article, it is reported that the fabr

10pt normal space after each heading/subheading/ paragraph and a single tab

tiple RES ions, which satisfactory gives optimal power to electrical utilization networks (loads) with redundancy control and maximum use of RES. The three phase inverter with multiple input of RES for a distributed energy management system as a whole automatically configure both a communication and a power line network, and then compose a master/slave relationship for fulfillment of linear, nonlinear and dynamic loading on the demand side. Also, it is entitled to give reliable energy to the demanded system. The monitored power system technical parameters through IP address can make distributed generation as a smart grid by addressing the data to cloud computing.

NOMENCLATURE

PD – Load demand Power
Pi – Inverter Output Power
PG – Existing Grid Power
Pdg – Diesel Generator Power
Pspv – Solar PV Power
Pwe – Wind Energy Power
Pb - Battery Power
Up - Active power output signal from inverter
Uq - Reactive power output signal from inverter
ξ_{ω} - Coefficient of frequency regulation
ξ_{V} - Coefficient of voltage regulation

ACKNOWLEDGMENT

For this research the received research grant is received from Savitribai Phule Pune University (Earlier named as University of Pune), Pune, Maharashtra, India, under research No. 15ENG002505 for year 2016–2018. Very much thankful to the management of Dr. D. Y. Patil Institute of Technology, Pimpri, Pune- 411018 Maharashtra, India for permission of testing our device at the rooftop and in the RES laboratory.

REFERENCES

[1] J. K. Yazdani A.; Di Fazio, A.R.; Ghoddami, H.; Russo, M.; Kazerani, M.; Jatskevich, J.; Strunz, K.; Leva, S.; Martinez, J.A., "Modeling Guidelines and a Benchmark for Power System Simulation Studies of Three-Phase Single-Stage Photovoltaic Systems," in IEEE Transactions on Power Delivery, Vol.26, No.2, pp.1247-1264, 2011.
[2] G.M.T. Nguyen and K. Uchida,"Active and Reactive Power Control Techniques Based on Feedback Linearization and Fuzzy Logic for Three-Phase Grid-Connected Photovoltaic Inverters," Asian J. Control, Vol. 17, No. 5, pp. 1522– 1546, 2015.
[3] A. Camacho, M. Castilla, J. Miret, A. Borrell, and L. G. de Vicuña, "Active and reactive power strategies with peak current limitation for distributed generation inverters during unbalanced grid faults," IEEE Trans. Ind. Electron., Vol. 62, No. 3, pp. 1515–1525, 2015.
[4] Huijuan Li; Yan Xu; Adhikari, S.; Rizy, D.T.; Fangxing Li; Irminger, P., "Real and reactive power control of a three-phase single-stage PV system and PV voltage stability," in Power and Energy Society General Meeting, 2012 IEEE, Vol.1, No. 8., pp. 22-26, 2012.
[5] Merabet, Adel & Labib, Labib & Mohammad Ghias, Amer Mohammad Yusuf " Robust Model Predictive Control for Photovoltaic Inverter System with Grid Fault Ride-Through Capability", IEEE Transactions on Smart Grid. PP. 1-1. 10.1109/TSG.2017.2694452.
[6] M. Rahimiyan and L. Baringo, "Strategic bidding for a virtual power plant in the day-ahead and real-time markets: A price-taker robust optimization method," IEEE Transactions on Power Systems , Vol. 31, No. 4, pp. 2676–2687, 2016.

[7] Y. Wang, X. Ai, Z. Tan, L. Yan, and S. Liu, “Interactive dispatch modes and bidding strategy of multiple virtual power plants based on demand response and game theory,” IEEE Transactions on Smart Grid, Vol. 7, No. 1, pp. 510–519, 2016.

[8] A. R. Abhyankar, S. A. Soman, and S. A. Khaparde, “Optimization method to real power tracing: an application to transmission fixed cost allocation,” IEEE Transactions on Power Systems , Vol. 21, No. 3, pp. 1350–1361, 2006.

[9] Vilas Bugade, Pradeep Katti,“Optimal Power Flow Method for Cognitive and Reliable Operation of Distributed Generation as Smart Grid “ Smart Grid and Renewable Energy, Vol. 8 , No.1, pp. 87 -98, 2018.

[10] Hannan, M.A.; Ghani, Z.A.; Mohamed, A. Uddin, M.N., "Real-time testing of a fuzzy logic controller based grid-connected photovoltaic inverter system," in Industry Applications Society Annual Meeting, 2014 IEEE , Vol.1, No.8., pp. 5-9 2014.

[11] Lal, V.N.; Singh, S.N., "Control and Performance Pursuit of a Single-Stage Utility-Scale Grid-Connected PV System," in Systems Journal, IEEE, Vol.2, No.99, pp.1-11, 2015.

[12] R. R. Jha and S. C. Srivastava, "Fuzzy Logic and ANFIS controller forgrid integration of Solar PhotoVoltaic," 2016 IEEE 6th International Conference on Power Systems (ICPS), New Delhi, Vol. 6, pp.1-6, 2016.

[13] R. R. Jha and S. C. Srivastava, M Kumar "Development of Control Schemes for a Cluster of PV Integrated Houses in Islanded Mode," IET Renewable Power Generation, Vol.10, No.2, pp.230-238, 2017.

[14] K. Mets, F. Depuydt, and C. Develder, “Two-stage load pattern clustering using fast wavelet transformation,” IEEE Transactions on Smart Grid, Vol. 7, No. 5, pp. 2250–2259, 2016.

[15] M. A. Tabrizi, and G. Radman, “Detailed Dynamic Modeling of Permanent Magnet Synchronous Machine based Wind Turbine for Power System Dynamic Exploration”, IEEE Southeastcon-2013, Acksonville, FL, USA, Vol. 1, No. 6, pp.4-7, .2013

[16] R. M. Pindoriya, N. M. Pindoriya, and S. Rajendran, “Simulation of DC/DC Converter for DC Nano Grid Integrated with Solar PVGeneration”, IEEE ISGT ASIA 2015, Bangkok, Thailand, pp. 1-6, November 3-6, 2015.

[17] L. Yujun, X. Zhao aand K.P.Wong, “Advanced Control Strategies of PMSG-Based Wind Turbines for System Inertia Support”, IEEE Transcation on power System, Vol. 32, No. 4, pp. 3027-3037, 2017.

[18] D. Chen, J. Zhang, and Z. Qian, “An improved repetitive control scheme for grid-connected inverter with frequency-adaptive capability,” IEEE Trans. Ind. Electron., Vol. 60,No. 2, pp. 814– 823, 2013.

[19] Li, Xiao, Haiyu Zhang, Mohammad B. Shadmand, and Robert Balog "Model Predictive Control of Voltage Source Inverter with Seamless Transition between Islanded and Gr id-connected Operations." IEEE Transactions on Industrial Electronics, Vol. 64, No.102, pp.7906 -7918, 2017.

[20] J. C. Dias and R. Hausmann, “A solar-powered VRLA battery chargecontroller using a dc-dc Cuk converter for a telemetry station power supply,” 2015 IEEE 13th Brazilian Power Electronics Conference and 1st Southern Power Electronics Conference (COBEP/SPEC), Fortaleza, pp. 1-5, Septmber 4 -7, 2015.

[21] M. A. Almozayen, M. K. Nemr, E. M. Rashad and A. I. Shobair, “ Finite-element-based design of axial field PMSG for wind energy conversion with MPPT control ”, Eighteenth International Middle East Power Systems Conference (MEPCON) , Cairo, pp. 610-616, December 27 -29, 2016.

[22] Albu, Mihaela M., Mihai Să nduleac, and Carmen St ă Nescu, "Syncretic use of smart meters for Power Quality monitoring in emerging networks." IEEE Transactions on Smart Grid, Vol.8, No. 1, pp. 485-492, 2017

[23] Vilas Bugade, Pradeep Katti, “Design with integrated active control of grid connected three phase inverter for multiple RES using DSP” International Journal of Latest Trends in Engineering and Technology, Vol.10, No.2, pp.143-149, 2018.

[24] N. Sharma, A. K. Chakraborty and A. Chakraborti, "Smart meter design with incorporated dynamic control of grid connected three phase inverter," 2017 7th International Conference on Power Systems (ICPS), Pune, 2017, pp. 677-683.

[25] D. Dharshana, M. Kolhe, A. Sharma, S. Garud, V. Dehalwar and V. K. Singh, "Evaluation of information and communication technologies for smart micro-grid automation," 2017 7th International Conference on Power Systems (ICPS), Pune, 2017, pp. 842-848.

[26] M.H.Rashid Power Electronics: Circuits, Devices and Applications, Pearson publications edition 2014, pp.53-54.

[27] Texas Instrument, “C2000 Delfino MCUs F28377S Launch Pad Development Kit,” 2015. [Online]. Available: http://www.ti.com/ tool/LAUNCHXL-F28377STechnical Documents.

[28] University of Washington Electrical Engineering, “Resources: Power systems test event archive,” 2016, [Online; accessed 7-March-2016]. [Online]. Available: https://www.ee.washington.edu/research/pstca/.M. Cha, H. Haddadi, F. Benevenuto, K. P. Gummadi, “Measuring User Influence in Twitter: The Million Follower Fallacy”, Proceedings of the International AAAI Conference on Weblogs and Social Media (ICWSM), May 2010.

AUTHOR PROFILES

Vilas Bugade (M’1975, J’01) received his degree in Electrical Engineering (B.E.) from Dr Babasaheb Ambedkar Marathwada University Aurangabad, Maharashtra, India in 1998 and Master of Engineering (M.E.) in Electrical Power Systems from PVG’s COET. Pune, India in 2007. Presently research scholar at Dr. Babasaheb Ambedkar Technological University (BATU), Lonere, Raigad, Maharashtra, India from august 2012.He is working as faculty member in Dr. D.Y.Patil

ITEE Journal
Information Technology & Electrical Engineering

ISSN: - 2306-708X

Institute of Technology, Pimpri, Pune affiliated to SPPU, Pune, India. His areas of interest are Hybrid Distributed Generation, Smart Grid, application of energy technology for rural areas and industries.

Dr. Pradeep Katti (M'1961, M'17) was born in 1961. He graduated from Mysore University's degree in Electrical Engineering (Power) from BIET Davanagere, in 1985. He obtained M.E (Control System) from Govt. College of Engineering of Pune University in 1991. He obtained Ph. D in Energy system from VNIT-Nagpur – India in 2007. He has wide teaching experience, and presently working with Dr. Babasaheb Ambedkar Technological University as professor in the Dept. of Electrical Engineering. He has guided projects at U.G. & P.G. and PhD research level. He has several Publications to his credit at international and national level.