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Voltage and Frequency Control of Isolated Hybrid Power Systems

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Abstract: — This paper proposes A hybrid VFDC/PQDC-based MG control scheme for Microgrid(MG) applications particularly islanded applications. A microgrid can be operated in both grid-connected and in autonomous mode. The control of autonomous MG is very complex without the support of public utility and grid. The control of virtual impedance plays an important role to decouple the active and reactive power allocations for energy storage systems (ESS). In this paper, ESSs control method is proposed with V/f droop control (VFDC) and P/Q droop control (PQDC) combined. The proposed method results are verified by using MATLAB SIMULINK.

Keywords— Energy storage system (ESS), microgrid (MG), P/Q droop, V/f droop.

I. INTRODUCTION

Generally a Microgrid (MG) has two modes of operations, they are a) autonomous operation mode; and b) grid-connected operation mode [1]–[3]. The control of an autonomous operation mode is very complex comparatively grid connected operation mode at where support of main grid is absent. Since inertia of MG is in smaller in size comparatively public grid, so the medium and small interruptions particularly the power fluctuations in solar arrays and wind turbines and also in load cut-off and load cut-in may lead to power quality issues. In these conditions to control the system voltage and frequency reliable power sources are required.

Energy storage system (ESS) can be controlled to release or absorb active/reactive power flexibly. With the appropriate control of active/reactive power by ESS, frequency and voltage can be maintained stable. [4]–[6]. constant voltage and frequency control (V/f) can be get by a single MPS for a medium or small size MG, which control ESS as a constant voltage/frequency source. For a large size MG two or more ESSs are required , which increases the system control complexity.V/f control method is usually invalid due to the loop current among the parallel connected ESSs.

Droop control is another method used to control the voltage and frequency, which imitates the characteristics of synchronous machine on the transmission level[7]. Based on the out-put active power and reactive power, the voltage angle and amplitude of each ESS is regulated respectively. Therefore, the active power and reactive power can be shared according the preset droop coefficient among the parallel ESSs, and the cut-in or cut-off of any of the ESS unit affects little to MG normal operation. Droop control makes power sources “plug and play” possible, which is an important feature for advanced MG [1].

Traditional droop control method is developed for high voltage (HV) transmission system in which the line impedance is very high. In MG the line impedance is resistive and the voltage levels are low/medium. So the traditional droop control method is not valid for MG due to active and reactive power coupling among ESSs, which will decrease the system transient response and steady-state performance [8]. In this situation due to the uncertainty of line impedance and control parameters the control process becomes more complex [9]. To make the power lines to be more inductive virtual impedance is used at converters [10]–[13].

This paper proposes a novel control method for ESSs-based MG which combines traditional V/f droop control (VFDC) with P/Q droop control (PQDC).The VFDC ESS provides the frequency and voltage determined by the actual active power and reactive power, while the PQDC ESS provides certain active power and reactive power determined by system frequency and voltage deviations from their nominal values.Since PQDC is independent of line parameters and other control errors, the interaction among ESSs can be avoided and system stability is improved. In this way, the frequency and voltage can be maintained stable through proper active power and reactive power distribution among all the parallel connected ESSs.

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The rest of this paper is organized as follows. Section II describes the features of MPSs with typical control methods for autonomous MG. Section III presents the proposed hybrid VFDC/PQDC control scheme. Section IV gives the experi-mental results. Finally, Section V presents the conclusion of this paper.

II. CONTROL OF MPS FOR AUTONOMOUS MG

As there is no synchronous generator available in MG, establishing and maintaining system frequency and voltage i.e, the choice and control of power supply is a big problem in autonomous MG operation.ESS with converter can be controlled flexibly with different output characteristics and is considered as a potential MPS for MG autonomous operation [21].(For an autonomous MG ,ESS can be considered as MPS when ESS placed with a converter)

Generally there are two methods to control ESS as a MPS a) V/f control b) droop control. Compared to V/f control, current sharing effect is good in droop control. So this paper focuses on droop control. Traditional droop control named in this paper as VFDC is analyzed and compared with the proposed hybrid VFDC/PQDC.

A. VFDC

Traditional synchronous characteristics are mimics by VFDC-based ESS with voltage angle and amplitude regulated according to its output active power and reactive power.

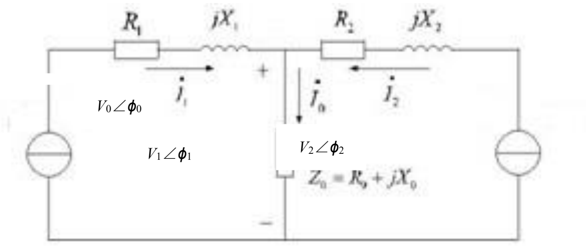

Fig. 1. MG equivalent circuit based on VFDC method.

The equivalent circuit of a MG with VFDC-based ESSs shown in Fig. 1, where the two ESSs are equivalent as voltage sources V1∠ϕ1 and V2∠ϕ2, respectively.

The load voltage($\overline{V}_0$) is derived as

The load voltage($\overline{V}_0$) is derived as

$$\overline{I_0} = \overline{I_1} + \overline{I_2}$$

So, $$\overline{V_0} = \frac{\frac{\overline{V_1}}{Z_1}+\frac{\overline{V_2}}{Z_2}}{\frac{1}{Z_0}+\frac{1}{Z_1}+\frac{1}{Z_2}} \qquad (1)$$

where $Z_1 = R_1 + jX_1$ and $Z_2 = R_2 + jX_2$ are equivalent line impedance of $V_1\angle\phi_1$ and $V_2\angle\phi_2$, respectively. The output current of the two voltage sources are

$$\overline{I_1} = \frac{\overline{V_1}-\overline{V_0}}{\overline{Z_1}} = \frac{(\overline{Z_2}+\overline{Z_0})\overline{V_1}-\overline{Z_0}\overline{V_2}}{Z_1Z_2+Z_0Z_2+Z_0Z_1} \qquad (2)$$

$$\overline{I_2} = \frac{\overline{V_2}-\overline{V_0}}{\overline{Z_2}} = \frac{(\overline{Z_1}+\overline{Z_0})\overline{V_2}-\overline{Z_0}\overline{V_1}}{Z_1Z_2+Z_0Z_2+Z_0Z_1} \qquad (3)$$

The apparent power of the two ESSs

$$\overline{S_1} = \overline{V_1} \times \overline{I_1}^* = \overline{V_1}^* \times \frac{(\overline{Z_2}^*+\overline{Z_0}^*)\overline{V_1}^*-\overline{Z_0}^*\overline{V_2}^*}{Z_1^*Z_2^*+Z_0^*Z_2^*+Z_0^*Z_1^*} \qquad (4)$$

$$\overline{S_2} = \overline{V_2} \times \overline{I_2}^* = \overline{V_2}^* \times \frac{(\overline{Z_1}^*+\overline{Z_0}^*)\overline{V_2}^*-\overline{Z_0}^*\overline{V_1}^*}{Z_1^*Z_2^*+Z_0^*Z_2^*+Z_0^*Z_1^*} \qquad (5)$$

where the superscript * is the corresponding conjugate phasors.

From the above eq.(2)-(5), it is clear that, the output current and apparent power of the two ESSs are dependent on the source voltage values($\overline{V_1}$, $\overline{V_2}$) and line impedances(Z_1, Z_2).

The current sharing of ESSs can only be implemented by the coordinated control of $\overline{V_1}$ and $\overline{V_2}$

$$\overline{I_1} = \overline{I_2}$$

$$\frac{(\overline{Z_2}+\overline{Z_0})\overline{V_1}-\overline{Z_0}\overline{V_2}}{Z_1Z_2+Z_0Z_2+Z_0Z_1} = \frac{(\overline{Z_1}+\overline{Z_0})\overline{V_2}-\overline{Z_0}\overline{V_1}}{Z_1Z_2+Z_0Z_2+Z_0Z_1} \qquad (6)$$

The phase angle difference between $\overline{V_1}$ and $\overline{V_2}$ is

$$\angle(\phi_2-\phi_1) = \frac{V_2}{V_1}\frac{(\overline{Z_1}+2\overline{Z_0})}{\overline{Z_2}+2\overline{Z_0}} \qquad (7)$$

Where ϕ_1 *and* ϕ_2, V_1 *and* V_2 are the phase angle and voltage amplitude of $\overline{V_1}$ *and* $\overline{V_2}$ respectively.

$$\cos(\phi_1-\phi_2) = \frac{V_2}{V_1}\frac{(2R_0+R_1)(2R_0+R_2)+(2X_0+X_1)(2X_0+X_2)}{(2R_0+R_2)^2+(2X_0+X_2)^2} \qquad (8)$$

$$\sin(\phi_1-\phi_2) = \frac{V_2}{V_1}\frac{(2X_0+X_1)(2R_0+R_2)-(2R_0+R_1)(2X_0+X_2)}{(2R_0+R_2)^2+(2X_0+X_2)^2} \qquad (9)$$

From eq (8) and (9) it is clear that the power distribution in the system is affected by line impedances, so it increases the complexity in control of ESS and current sharing effect reduces due to the uncertainty in line parameters.

B. Hybrid VFDC/PQDC

PQDC-based ESS controls its output active power and reactive power based on MG frequency and voltage changes from their rated values. Let the ESS V_2 is regulated by PQDC, then the equivalent circuit shown in fig.1 can be described as a connection of $V_1\angle\phi_1$ and $I_2\angle\phi_2$ as shown below.

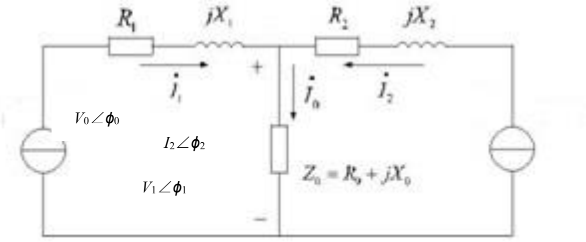

Fig. 2. MG equivalent circuit based on PQDC method.

By applying KCL and KVL, $\overline{I_1} = \frac{\overline{V_1}-\overline{I_2}Z_0}{Z_0+Z_1}$ (10)

And $\overline{S_1} = \overline{V_1}\times\overline{I_1}^* = \overline{V_1}^*\times\left(\frac{\overline{V_1}-\overline{I_2}Z_0}{Z_0+Z_1}\right)^* = \frac{V_1{}^2-\overline{Z_0}^*\overline{I_2}^*\overline{V_1}}{Z_0{}^*+Z_1{}^*}$ (11)

From eq(11), $\overline{S_1}$ is not depends on Z_2. If $\overline{V_1}$ and line parameters are given, then $\overline{S_1}$ can found only by the value of $\overline{I_2}$ .From the above we can say that , the diversity and uncertainty in line parameters(Z1, Z2) has no impact on MG power regulation. This means that the hybrid VFDC/PQDC system is better in current sharing control than the VFDC system.

III. PROPOSED HYBRID VFDC/PQDC CONTROL SCHEME

The VFDC-based ESS is controlled as a V/f droop voltage source with output voltage and frequency determined by its active power and reactive power. While the PQDC-based ESS is controlled as a P/Q source with output active power and reactive power determined by the voltage and frequency deviations on its output terminal. To decouple the active power and reactive power due to the resistive line parameters, virtual impedance control is adopted.

A. Virtual Impedance Control

From [22], the real and reactive power allotted to two converters connected to a common bus are given as

$$P = \left(\frac{EV}{Z}\cos\emptyset - \frac{V^2}{Z}\right)\cos\theta + \frac{EV}{Z}\sin\emptyset\sin\theta \qquad (12)$$

$$Q = \left(\frac{EV}{Z}\cos\emptyset - \frac{V^2}{Z}\right)\sin\theta - \frac{EV}{Z}\sin\emptyset\cos\theta \qquad (13)$$

where E and V are the amplitudes of converters output voltage and bus voltage, $\emptyset$ is the power angle, Z and θ are the magnitude and the phase of output impedance.
For HV transmission system line impedance is more inductive, so θ is assumed as 90°, Z ≈ X , where X is line reactance.
Then the above eq(12-13) are

$$P = \frac{EV}{X}\sin\emptyset\,; \quad Q = \frac{EV\cos\emptyset - V^2}{X} \qquad (14)$$

For low voltage distribution line impedance is more resistive in nature so θ is assumed as 0°, Z ≈ R , where R is line resistance.
Then the above eq(12-13) are

$$P = \frac{EV\cos\emptyset - V^2}{R}\,, \quad Q = -\frac{EV}{R}\sin\emptyset \qquad (15)$$

By observing eq (14) and (15), the real and reactive power distribution between converters is effected by line impedance. low/medium voltage MG has the line impedance as resistive but the P−f and Q−v decoupling of traditional droop control is done on inductive impedance. So to control MG, we have to make the line impedance to be inductive [23], this can be done with the help of Virtual impedance control method, which makes the converter output impedance to be inductive and then the total impedance is inductive [19]

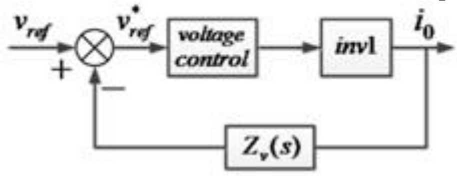

Fig. 3. Schematic of virtual impedance control loop

The schematic virtual impedance control loop is shown in fig.3, where $Z_v(s)$ is the virtual impedance equivalent as an inductor L_v.

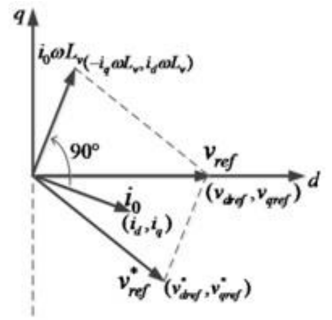

Fig. 4. Phasor diagram of virtual impedance control based on d-q axis.

Truly speaking virtual impedance is a voltage correction method, as shown in fig.4, where v_{ref} is the reference voltage, $v^*{}_{ref}$ is that after modification, i_0 is the output current, and $i_0\omega L_v$ is the voltage drop on virtual inductor L_v.

The reference output voltage can be given as,

$$v^*{}_{dref} = v_{dref} + i_q\omega L_V \qquad (16)$$
$$v^*{}_{qref} = v_{qref} + i_d\omega L_V \qquad (17)$$

As a result, the equivalent impedance is controlled to be inductive which enables P−f and Q−v decoupling. Moreover, the active and reactive current sharing among the parallel connected ESSs can be improved since their output impedances
are definite.

B. VFDC Control

The VFDC-based ESS is controlled to output certain frequency and voltage according to its active and reactive power. Since the virtual inductor L_v will absorb certain reactive power Q_v, it is taken as a correction to the reactive power reference Q^*.The droop control loop with reactive power compensation is illustrated in Fig. 5.

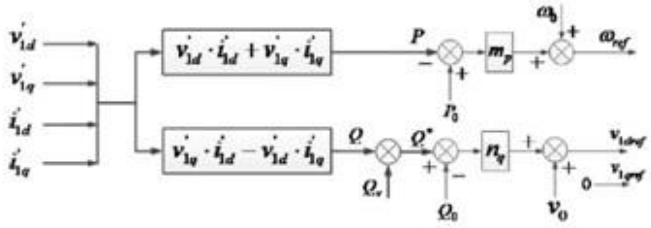

Fig. 5. VFDC control loop with reactive power compensation.

$$\omega_{ref} = \omega_0 + m_p(P_0 - P)$$
$$v_{ref} = v_0 + n_q({Q_0}^* - Q) \qquad (17)$$

Where, ω_{ref} , v_{ref} are the reference frequency and voltage of VFDC converter, P_0, Q_0 are the rated active and reactive power, P and Q are the actual active and reactive power output, m_p and n_q are the droop coefficient of active and reactive power for VFDC, ω_0, v_0 are the nominal frequency and voltage respectively.

By finding the ω_{ref}, v_{ref} the VFDC based converter control can be implemented with the virtual impedance loop, voltage loop and current loop shown in fig.6.

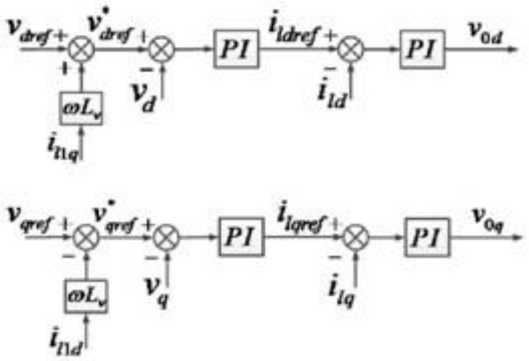

Fig. 6. Virtual impedance loop, voltage loop, and current loop of VFDC (i_{l1d}*ωLv and i_{l1q}*ωLv denote the virtual impedance loop, respectively).

C. PQDC Control

The PQDC-based ESS is controls certain active power and reactive power based on the system frequency and local voltage chnages from their rated values.

Same as in VFDC control, in the droop control loop with the help of virtual inductor voltage v_v, the reference voltage v^* is corrected to compensate the drop in virtual inductor L_v as shown in fig.7.

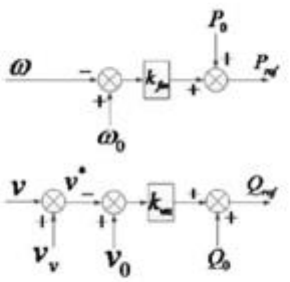

Fig. 6. PQDC control loop with voltage correction

$P_{ref} = P_0 + k_{fm}(\omega_0 - \omega)$
$Q_{ref} = Q_0 + k_{vn}(v_n - v^*)$ (18)

where k_{fm} and k_{vn} are the droop coefficient of frequency and voltage for PQDC.

By finding P_{ref} and Q_{ref} , the PQDC converter control can be implemented with the virtual impedance loop, voltage loop and current loop as shown in fig.8 and 9 respectively.

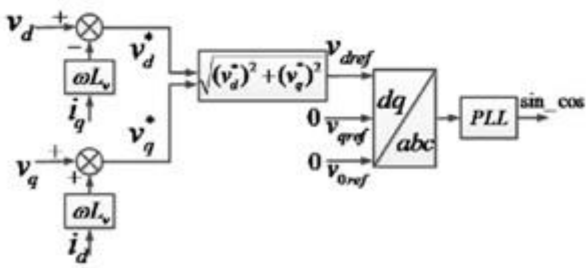

Fig. 8. Virtual impedance loop of PQDC.

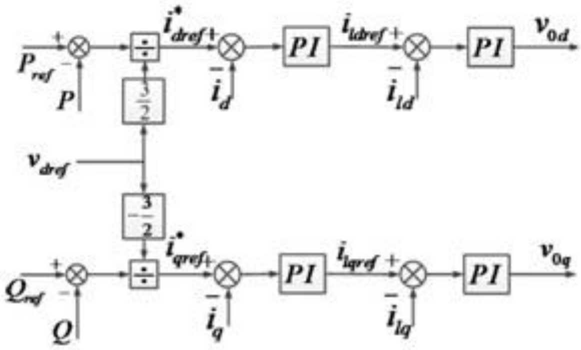

Fig. 9. Voltage and current loop of PQDC.

IV. Simulation Results and Discussion

In this paper autonoumus microgrid performance is evaluated in terms of drooping characteristics of voltage with extensive MATLAB Simulations are carried out by varying load parameters.

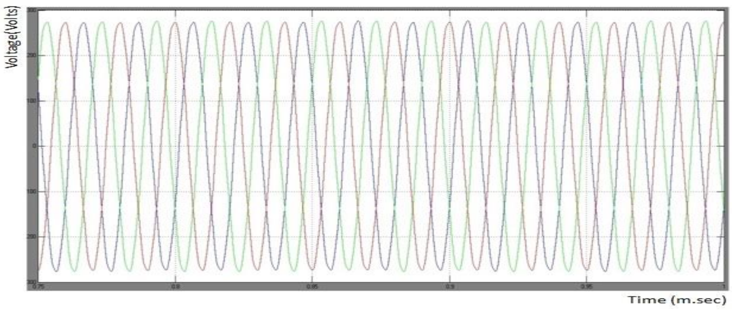

Fig10: Voltage characteristics of MG at 1000KW resistive load, 100KVAR inductive load, 50KVAR capacitive load

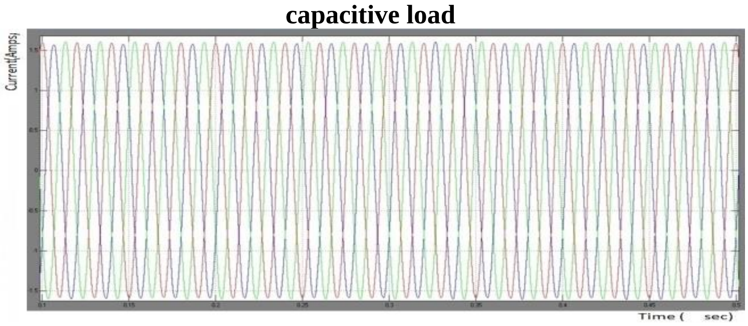

Fig11: Current characteristics of MG at 1000KW resistive load, 100KVAR inductive load, 50KVAR capacitive load

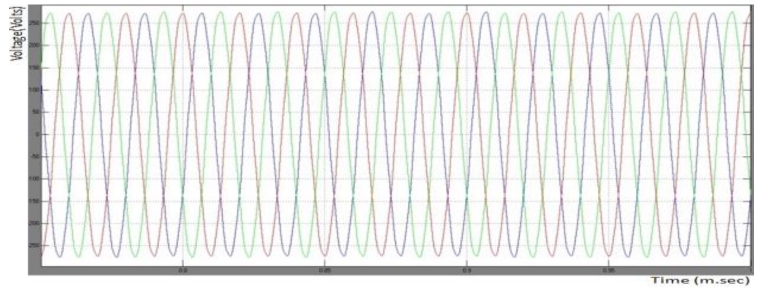

Fig12: Voltage characteristics of MG at 1200KW resistive load, 150KVAR inductive load, 80KVAR capacitive load

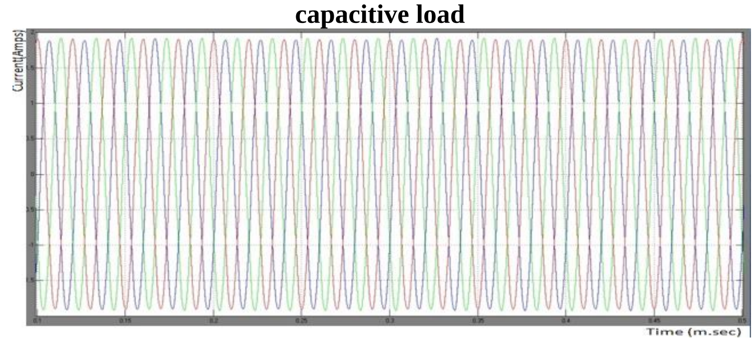

Fig13: Current characteristics of MG at 1200KW resistive load, 150KVAR inductive load, 80KVAR capacitive load

Table1: Voltage and frequency of MG at various loads

P	Q_L	Q_C	V	I	f	T.H.D
800	80	40	276	1.3	50	1.77
1000	100	50	275	1.6	50	1.85
1200	150	80	274	1.75	50	1.85
1500	200	100	272	2.5	50	1.9

V. CONCLUSION

In This paper a hybrid VFDC/PQDC droop control scheme for ESS-based autonomous MG. The proposed control structure VFDC ESS controls voltage angle and amplitude based on the active and reactive power, and PQ droop controlled ESS controls the active and reactive power output based on frequency and voltage deviations from the nominal values. The hybrid VFDC/PQDC can prevent the interference of line impedance uncertainty. The basic operation principle and control scheme of ESSs-based MG with hybrid VFDC/PQDC control is analyzed in detail.

REFERENCES

[1] R. H. Lasseter, “Microgrids,” in *Proc. IEEE Power Eng. Soc. Winter Meeting*, New York, NY, USA, Jan. 2002, pp. 305–308.

[2] A. G. Tsikalakis and N. D. Hatziargyriou, “Centralized control for opti-mizing microgrids operation,” *IEEE Trans. Energy Convers.*, vol. 23, no. 1, pp. 241–248, Mar. 2008.

[3] H. Nikkhajoei and R. H. Lasseter, “Distributed generation interface to the CERTS microgrid,” *IEEE Trans. Power Del.*, vol. 24, no. 3,
pp. 1598–1608, Jul. 2009.

[4] X. Tang and Z. Qi, “Energy storage control in renewable energy based microgrid,” in *Proc. IEEE Power Energy Soc. Gen. Meeting*, San Diego, CA, USA, Jul. 2012, pp. 1–6.

[5] J. Y. Kim *et al.*, “Cooperative control strategy of energy storage system and microsources for stabilizing the microgrid during islanded opera-tion,” *IEEE Trans. Power Electron.*, vol. 25, no. 12, pp. 3037–3048, Dec. 2010.

[6] X. Tang, W. Deng, and Z. Qi, “Investigation of the dynamic stability of microgrid,” *IEEE Trans. Power Syst.*, vol. 29, no. 2, pp. 698–706, Mar. 2014.

[7] M. C. Chandorkar, D. M. Divan, and R. Adapa, “Control of parallel connected inverters in standalone

AC supply systems," *IEEE Trans. Ind. Appl.*, vol. 29, no. 1, pp. 136–143, Jan./Feb. 1993.
[8] Y. Li and C.-N. Kao, "An accurate power control strategy for power-electronics-interfaced distributed generation units operating in a low-voltage multibus microgrid," *IEEE Trans. Power Electron.*, vol. 24, no. 12, pp. 2977–2988, Dec. 2009.
[9] J. A. P. Lopes, C. L. Moreira, and A. G. Madureira, "Defining control strategies for microgrid islanded operation," *IEEE Trans. Power Syst.*, vol. 21, no. 2, pp. 916–924, May 2006.
[10] J. M. Guerrero *et al.*, "Wireless-control strategy for parallel operation of distributed-generation inverters," *IEEE Trans. Ind. Appl.*, vol. 53, no. 5,
pp. 1461–1470, Oct. 2006.
[11] J. M. Guerrero *et al.*, "Droop control method for the parallel operation of online uninterruptible power systems using resistive output impedance," in *Proc. 21st Annu. IEEE Appl. Power Electron. Conf. Expo. (APEC)*, Dallas, TX, USA, Mar. 2006, pp. 1716–1722.
[12] J. M. Guerrero *et al.*, "Droop control method with virtual output impedance for parallel operation of uninterruptible power supply sys-tems in a microgrid," in *Proc. 22nd Annu. IEEE Appl. Power Electron. Conf. (APEC)*, Anaheim, CA, USA, Mar. 2007, pp. 1126–1132.
[13] J. He *et al.*, "An islanding microgrid power sharing approach using enhanced virtual impedance control scheme," *IEEE Trans. Power Electron.*, vol. 28, no. 11, pp. 5272–5282, Nov. 2013.
[14] E. Barklund *et al.*, "Energy management in autonomous microgrid using stability-constrained droop control of inverters," *IEEE Trans. Power Electron.*, vol. 23, no. 5, pp. 2346–2352, Sep. 2008.
[15] Tabassum, Saleha, and B. Mouli Chandra. "Power Quality improvement by UPQC using ANN Controller." International Journal of Engineering Research and Applications 2.4 (2012): 2019-2024.
[16] Chandra, B. Mouli, and Dr S. Tara Kalyani. "FPGA controlled stator resistance estimation in IVC of IM using FLC." Global Journal of Researches in Engineering Electrical and Electronics Engineering 13.13 (2013).
[17] Chandra, B. Mouli, and S. Tara Kalyani. "Online identification and adaptation of rotor resistance in feedforward vector controlled induction motor drive." Power Electronics (IICPE), 2012 IEEE 5th India International Conference on. IEEE, 2012.
[18] Chandra, B. Mouli, and S. Tara Kalyani. "Online estimation of Stator resistance in vector control of Induction motor drive." Power India Conference, 2012 IEEE Fifth. IEEE, 2012.
[19] MURALI, S., and B. MOULI CHANDRA. "THREE PHASE 11-LEVEL INVERTER WITH REDUCED NUMBER OF SWITCHES FOR GRID CONNECTED PV SYSTEMS USING VARIOUS PWM TECHNIQUES."
[20] BABU, GANDI SUNIL, and B. MOULI CHANDRA. "POWER QUALITY IMPROVEMENT WITH NINE LEVEL MULTILEVEL INVERTER FOR SINGLE PHASE GRID CONNECTED SYSTEM."
[21] NAVEENKUMAR, K., and B. MOULI CHANDRA. "Performance Evaluation of HVDC Transmission system with the Combination of VSC and H-Bridge cells." Performance Evaluation 3.02 (2016).
[22] Vijayalakshmi, R., G. Naga Mahesh, and B. Mouli Chandra. "Seven Level Shunt Active Power Filter for Induction Motor Drive System." International Journal of Research 2.12 (2015): 578-583.
[23] BAI, RM DEEPTHI, and B. MOULI CHANDRA. "Speed Sensorless Control Scheme of Induction Motor against Rotor Resistance Variation." (2013).
[24] Chandra, B. Mouli, and S. Tara Kalyani. "Online Rotor Time Constant Tuning in Indirect Vector Control of Induction Motor Drive." International Journal on Engineering Applications (IREA) 1.1 (2013): 10-15.
[25] Rajesh, P., Shajin, F. H., Mouli Chandra, B., & Kommula, B. N. (2021). Diminishing Energy Consumption Cost and Optimal Energy Management of Photovoltaic Aided Electric Vehicle (PV-EV) By GFO-VITG Approach. Energy Sources, Part A: Recovery, Utilization, and Environmental Effects, 1-19.
[26] Reddy C, Narukullapati BK, Uma Maheswara Rao M, Ravindra S, Venkatesh PM, Kumar A, Ch T, Chandra BM, Berhanu AA. Nonisolated DC to DC Converters for High-Voltage Gain Applications Using the MPPT Approach. Mathematical Problems in Engineering. 2022 Aug 22;2022.
[27] Sravani, B., C. Moulika, and M. Prudhvi. "Touchless door bell for post-covid." South Asian Journal of Engineering and Technology 12.2 (2022): 54-56.
[28] Mounika, P., V. Rani, and P. Sushma. "Embedded solar tracking system using arduino." South Asian

Journal of Engineering and Technology 12.2 (2022): 1-4.

[29] Prakash, A., Srikanth, T., Moulichandra, B., & Krishnakumar, R. (2022, February). Search and Rescue Optimization to solve Economic Emission Dispatch. In 2022 First International Conference on Electrical, Electronics, Information and Communication Technologies (ICEEICT) (pp. 1-5). IEEE.

[30] Kannan, A. S., Srikanth Thummala, and B. Mouli Chandra. "Cost Optimization Of Micro-Grid Of Renewable Energy Resources Connected With And Without Utility Grid." Materials Today: Proceedings (2021).

[31] Chandra, B. M., Sonia, D., Roopa Devi, A., Yamini Saraswathi, C., Mighty Rathan, K., & Bharghavi, K. (2021). Recognition of vehicle number plate using Matlab. J. Univ. Shanghai Sci. Technol, 23(2), 363-370.

[32] Noushin, S. K., and Daka Prasad2 Dr B. Mouli Chandra. "A Hybrid AC/DC Micro grid for Improving the Grid current and Capacitor Voltage Balancing by Three-Phase AC Current and DC Rail Voltage Balancing Method."

[33] Deepika, M., Kavitha, M., Chakravarthy, N. K., Rao, J. S., Reddy, D. M., & Chandra, B. M. (2021, January). A Critical Study on Campus Energy Monitoring System and Role of IoT. In 2021 International Conference on Sustainable Energy and Future Electric Transportation (SEFET) (pp. 1-6). IEEE.

[34] ANITHA, CH, and B. MOULI CHANDRA. "A SINGLE-PHASE GRID-CONNECTED PHOTOVOLTAIC INVERTER BASED ON A THREE-SWITCH THREE-PORT FLYBACK WITH SERIES POWER DECOUPLING CIRCUIT."

[35] Sai, V. N. V., Kumar, V. B. C., Kumar, P. A., Pranav, I. S., Venkatesh, R., Srinivasulu, T. S., ... & Chandra, B. M. Performance Analysis of a DC Grid-Based Wind Power Generation System in a Microgrid.

[36] Prakash, A., R. Anand, and B. Mouli Chandra. "Forward Search Approach using Power Search Algorithm (FSA-PSA) to solve Dynamic Economic Load Dispatch problems." 2019 5th International Conference on Advanced Computing & Communication Systems (ICACCS). IEEE, 2019.

[37] K Balasamy, N Krishnaraj, K Vijayalakshmi "Improving the security of medical image through neuro-fuzzy based ROI selection for reliable transmission" Journal of Multimedia Tools and Applications, Springer US, Page no. 14321-14337Vol:81, 4/2022.

[38] M. Jeyaselvi, C. Jayakumar, M. Sathya, S. J. A. Ibrahim and N. S. Kalyan Chakravarthy, "Cyber security-based Multikey Management System in Cloud Environment," 2022 International Conference on Engineering and Emerging Technologies (ICEET), Kuala Lumpur, Malaysia, 2022, pp. 1-6, doi:10.1109/ICEET56468.2022.10007104, https://ieeexplore.ieee.org/abstract/document/10007104

[39] S. Jafar Ali Ibrahim et al., "Rough set based on least dissimilarity normalized index for handling uncertainty during E-learners learning pattern recognition", International Journal of Intelligent Networks, Volume 3, 2022, Pages 133-137, ISSN 2666-6030, https://doi.org/10.1016/j.ijin.2022.09.001.(https://www.sciencedirect.com/science/article/pii/S2666603022000148)

[40] Ibrahim,S. Jafar Ali, Rajasekar S. Chakravarthy N. S. Kalyan, Varsha, Singh Maninder Pal , Kumar Vaneet and Saruchi Synthesis, Characterization of Ag/Tio2 Nanocomposite: Its Anticancer and Anti-Bacterial and Activities, Global Nest, Volume 24, Issue 2, June 2022, Pages:262-266, Issn No: 1790-7632, DOI: https://doi.org/10.30955/gnj.0042505

[41] Linjiang Xie, Feilu Hang, Wei Guo, Yao Lv, Wei Ou, and C. Chandru Vignesh "Machine learning-based security active defence model - security active defence technology in the communication network "International Journal of Internet Protocol Technology 2022 15:3-4, 169-181 https://doi.org/10.1504/IJIPT.2022.125955

[42] KexuWu, Chaolin Li, Chandru Vignesh C, Alfred Daniel J "Digital teaching in the context of Chinese universities and their impact on students for Ubiquitous Applications" Computers and Electrical Engineering, Volume 100, May 2022, 107951, https://doi.org/10.1016/j.compeleceng.2022.107951

[43] Huiyi Zang, C Chandru Vignesh and J Alfred Daniel "Influence of Social and Environmental Responsibility in Energy Efficiency Management for Smart City"Journal of Interconnection Networks, Vol. 22, No. Supp01, 2141002 (2022), https://doi.org/10.1142/S0219265921410024

[44] R Menaha, VE Jayanthi, N Krishnaraj," A Cluster-based Approach for Finding Domain wise Experts in Community Question Answering System", Journal of Physics: Conference Series, Volume: 1767, IOP Publishing, 2021. DOI 10.1088/1742-6596/1767/1/012035.

[45] J Ramprasath, M Aswin Yegappan, Dinesh Ravi, N Balakrishnan and S Kaarthi, Assigning Static Ip Using DHCP In Accordance With MAC, INTERNATIONAL JOURNAL FOR TRENDS IN ENGINEERING & TECHNOLOGY, Vol 20, Issue 1, 2017.

[46] J Ramprasath, Dr S Ramakrishnan, P Saravana Perumal, M Sivaprakasam, U Manokaran Vishnuraj, Secure network implementation using VLAN and ACL, International Journal of Advanced Engineering Research and Science, Vol 3, Issue 1, PP. 2349-6495, 2016

[47] J Ramprasath, V Seethalakshmi, Secure access of resources in software-defined networks using dynamic access control list, International Journal of Communication Systems, Vol 34, Issue 1, PP. e4607, 2020.

[48] Balasamy, K., Krishnaraj, N. & Vijayalakshmi, K. An Adaptive Neuro-Fuzzy Based Region Selection and Authenticating Medical Image Through Watermarking for Secure Communication. Wireless Pers Commun 122, 2817–2837 (2022). https://doi.org/10.1007/s11277-021-09031-9