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Stability Analysis of AI Technique Based Dynamics Control in Renewable Energy Interfaced Grid Systems

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***Abstract*— Energy incorporates a very important role for the development of a nation and it's to be preserved in a very most effective manner. Energy is that the ultimate issue accountable for each industrial and agricultural development. Power Quality issues are harmonics and voltage and frequency fluctuations. To study the system performance under the effect renewable energy based generating units the kundur's two area system has been taken as test system. The direct integration of these resources were studied for various instability issues like rotor angle stability, power stability at the generating points of machines and distortion level in the voltage and current waveforms of the grid system. The work has proposed a universal dynamic system optimizing control for system stability enhancement in all the aspects utilizing NN and AI-based differential evolutionary optimizing algorithm. The proposed differential evolutionary with NN learning-based control of the dynamic system optimizing control for system stability enhancement can be a better option for integrating any type of renewable energy resource-based generating system with the grid as it can mitigate most of the quality issues arising due to it.**

***Keywords*— DFIG, STATCOM, Renewable energy, STATCOM control.**

I. INTRODUCTION

Energy incorporates a very important role for the development of a nation and it's to be preserved in a very most effective manner. Energy is that the ultimate issue accountable for each industrial and agricultural development. The new technologies that are developed to provide energy within the most environmental friendly manner and conservation of energy resources in most economical means has equal importance. The utilization of renewable energy technology to satisfy the energy demands has been steady increasing for the past few years. Import of petroleum products constitutes a serious drain on our foreign exchange reserve.

A. Hybrid System

The large-scale wind/solar hybrid system is connected to grid via a booster station. The system consists of wind power system and photovoltaic system. In order to improve the transient voltage stability of the large-scale wind/solar hybrid system, reactive power compensation device SVC (Static Var Compensator, SVC) is connected to grid. The wind power generation system consists of DFIG wind turbine and boost transformer. The output of the wind power generation system is limited by wind speed, dispatching commands and photovoltaic power.

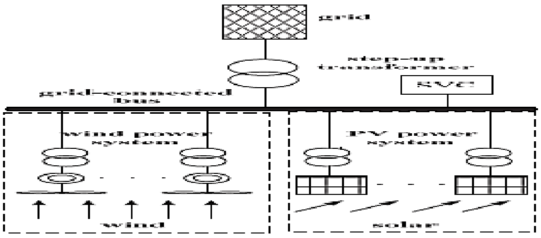

Fig 1: Diagram of wind/solar hybrid system

It is worth noting that, SVC provides or absorbs reactive power by detecting the voltage at the parallel point with grid when the external fault occurs in grid. With the help of SVC, the voltage of grid connected bus is maintained.

B. Hybrid energy system (HES)

It will be good to start with the Hybrid Energy System (HES). The hybrid power system is the technical design where the power components are hybrid or coupled. For example, organizing different energy resources to work in parallel (equivalent) is widely used in power supply.

Hybridization is therefore defined as the formation of a cross between pairs of agents to work together to achieve a goal.

C. Hybrid renewable energy power system (HREPS)

The Hybrid Power System for Renewable Energy (HREPS) is a cross or a mixture of an adequate (parallel) electrical grid infrastructure that provides reliable power. The hybrid renewable energy system (HREPS) has huge designs or models composed of five common subunits, namely (i) renewable energy source (RER) or energy recuperator, (ii) electrical system (air conditioner energy) and (iii) energy storage system (ESS), (iv) a common bus and (v) an electronic logic controller (ECS) are included for system management. Therefore, HREPS has several hybridization projects through an optimal selection of suitable components including energy recovery, electric power conditioner, ESS, common bus and electronic logic control.

D. Controller For Solar and Wind Hybrid Power System

The main problems with wind and solar hybrid systems are energy quality and voltage stability. Since both sources are renewable, the performance of each source depends on the type. Wind speed is not always constant and sunlight also varies throughout the day. The solar system does not function during the rainy season. For this reason the voltage is not constant and the quality of the current suffers.

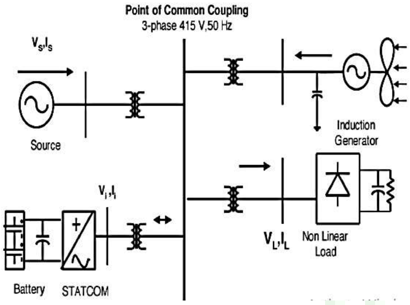

Fig..2: Grid connected FACT system for power quality improvement

II. LITERATURE REVIEW

Mohammad Javad Morshed et al. [1] This paper proposes a novel non-linear control approach for the coordination of DFIG and STATCOM (Static Synchronous Compensator) wind turbine controllers in multi-machine power systems. The main goal is to improve the transient and voltage stability of the interconnected multi-machine power supply system by simultaneously designing the DFIG rotor voltage and the STATCOM reference current. The non-linear approach is based on Zero Dynamic Range (ZD) Multi Input-Multi Output (MIMO) technology, which is complemented by Super Torsion Sliding Mode Control (STSMC) to reduce the effects of linearization error. The proposed approach was implemented on the Kundur four machine dual surface power system and the IEEE 39 bus power system. Performance was evaluated under different failure and malfunction scenarios.

Konstantin Schaab et al. [2] On the other hand, a uniform synthesis scheme of regulators is proposed in this work, which together deals with the stability of the rotor angle and the stability of the voltage of networks containing synchronous generators and energy conversion systems. Wind turbine based on double power induction generators. . First, a method is proposed for describing production units using Linear Parameter Variant (LPV) systems in which network or windimposed fluctuations are mapped into time-varying model parameters. For adequate ranges of these parameters, decentralized and robust controls can be synthesized from the semi-finished programming so that the power grid is stabilized for the fluctuations and disturbances under consideration. The effectiveness of the approach is demonstrated for a multi-bus reference system where the network oscillations are well damped and the LPV controller stabilizes the network after permanent changes.

E. Sharifi et al. [3] this research focuses on the transient stability of multi-machine propulsion systems, fully taking into account the performance of the Takagi-Sugeno blur-based scroll mode control approach in combination with the conventional scroll mode, as well as the approaches. Final results in this area. As regards the robustness of the sliding mode control approach to parametric uncertainties and environmental disturbances, below, some different sliding mode control approaches are in fact designed for mutual comparison after a series of considerations of the prior art. In order to increase the control performance, the Takagi-Sugeno-Fuzzy based approach was developed to provide the appropriate coefficients. Finally, the three control approaches are all run in the six-machine power system under the same conditions and the examined results are made available for analysis accordingly. The results show that the proposed fuzzy control approach works well compared to other related approaches.

A. Kanchanaharuthai et al. [4] This article examines the application of STATCOM and battery energy storage systems to improve transition stability of large multi-machine utility systems with synchronous and dual-feed induction generators (DFIG). For multi-machine power systems, a passivity-based control design method [passivity-based control for interconnection and attenuation assignment (IDA-PBC)] has been developed, including performance assessed on a two surface system consisting of two generators (SG) and two DFIG with STATCOM / battery energy storage system.

Schaab K et al. [5] On the other hand, a uniform synthesis scheme of regulators is proposed in this work, which together deals with the stability of the rotor angle and the stability of the voltage 10 of networks containing synchronous generators and energy conversion systems. Wind turbine based on double power induction generators. .

First, a method is proposed for describing production units using Linear Parameter Variant (LPV) systems in which network or windimposed fluctuations are mapped into time-varying model parameters. For appropriate ranges of these parameters, robust decentralized controls can be synthesized by semifinal programming, so that the power grid is stabilized for the fluctuations and disturbances under consideration. The effectiveness of the approach is demonstrated for a multi-bus reference system where the network oscillations are well damped and the LPV controller stabilizes the network after permanent changes.

Darabian M et al. [6] The main objective of this article, which distinguishes it from other similar articles, is to apply a predictive control strategy to improve the stability of electrical systems (4 machines and 10 machines) in the presence of wind farms based on an induction generator feed (DFIG) using a synchronous series static compensator (SSSC) and a super capacitor energy storage system (SCESS). In this article, SCESS is used to control the actual power in the Grid Side Converter (GSC) and SSSC is used to reduce low frequency oscillations. The proposed strategy based on predictive control can be used simultaneously to control the active and reactive power of the rotor side converter (RSC), as well as the attenuation controller design for SCESS and SSSC.

Godpromesse K et al. [7] An adaptive nonlinear controller for transient stability and voltage regulation of DFIG-based power systems in multi-machine configuration is presented using a standard third-order dynamic model of DFIG. Finite-time estimators are presented for the non-measurable time derivative of the quadrature component of the DFIG stator current, mechanical input, transient open-loop time constant of the unknown direct axis (function of rotor resistance).

Haotian K et al. [8] This article proposes a Switch Tissue Excitation Regulator (SSEC) to improve the transition stability of multi-machine feeding systems. SSEC switches from a bang-bang funnel excitation regulator (BFEC) to a conventional excitation regulator (CEC) based on a properly designed state-dependent switching strategy. Only the rotor angle following error is needed to implement BFEC with two control values in bang-bang mode. If the BFEC feasibility assumptions are met, the rotor angle following error can be adjusted within the predefined error funnels.

III. MODLEING TWO AREA SYSTEM

Rotor angular stability refers to the ability to maintain / regain synchronicity after suffering a disturbance in an interconnected network. In normal system operation, all synchronous machines rotate at the same electrical speed 2πf. The mechanical and electromagnetic couples acting on the rotating masses of each generator are counterbalanced and the differences in phase shift between the internal electromagnetic fields of the various machines are constant and remain synchronous. After a malfunction, a change in rotor speed occurs due to torque imbalance, which leads to loss of synchronism.

To analyze grid stability with two machine systems in zone 4, we integrated several renewable energy sources and examined the effects of integration on them. Kundur's two-surface system is initially used as a test model, which is subject to a) wind energy integration b) solar / wind hybrid system integration and c) solar / wind energy integration. The test system is completely modified with three renewable energy systems for power generation. Stability is examined on the machine and spawn points after integration.

A. Development of test system :-In general, a bus in an electrical power system is fed from the generating units which inject the active and reactive power into it and loads real and reactive power s from it. [n load flow studies, the generator and load (complex) powers are lumped into a net power. This net power is called bus injected power. The net power injected in the bus is given by:

$$S = P + jQ = PG + JQG - PD + JQD \quad \ldots\ldots(1)$$

The test system chosen comprises of two areas with four machines. The system is integrated with the highly variable feeding wind energy resource. The single line diagram of the sytem has been depicted in figure.

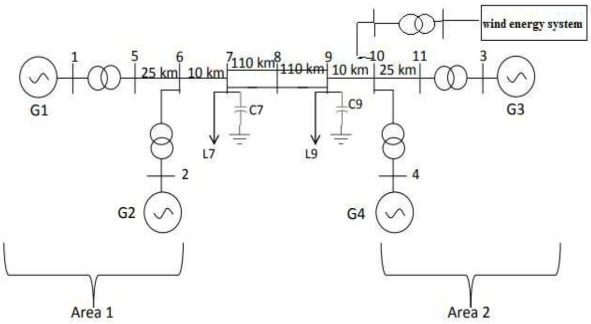

Fig. 3: Single line diagram of two area system on wind integration

IV. FEED FORWARD NEURAL LEARNING AND OPTIMIZATION

Feed forward Neural network based learning of system dynamics arriving at the integration

ANNs are information processing systems that simulate human behavior. The ANNs obtain information about the characteristics considered and learn from the input data, even if our model contains noise. The structure of the ANN consists of essential information processing units, which are neurons. They are divided into several layers and linked together by defining weights. The synaptic weights show the interaction between each pair of neurons. These structures distribute information across neurons. The mapping of the input and the estimated responses of the output are calculated by combining several transfer functions. We can use the self-adaptive information shape recognition method to analyze the training algorithms of artificial neural networks.

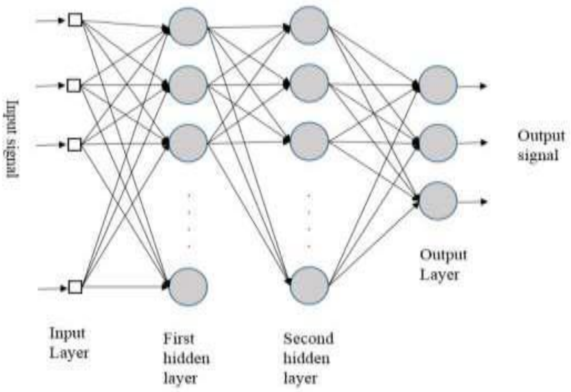

Fig. 4 Architectural Graph of an MLP Network with Two Hidden Layers.

Neural networks can be divided into single-layer perception networks and multilayer perception networks (MLPs). The multilayer perceptual network comprises several layers of simple two-state sigmoid transfer functions with processing neurons interacting by applying weighted connections. A typical multilayer neural network consists of the input layer, the output layer, and the hidden layer. Multilayer perception (MLP) with the back propagation learning algorithm is used in this study because many previous researchers have used this type of ANN and it is also an approximation of general functions.

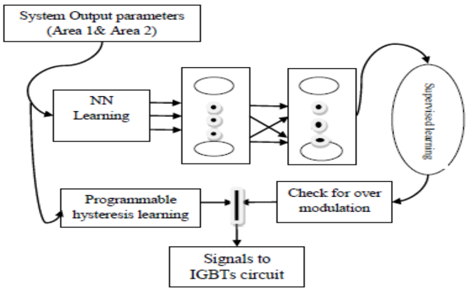

Fig. 5: DE – NN controller Technique implemented in MATLAB/SIMULINK

The development of the ANN models was based on the study of the relationship between input variables and output variables. Basically, the neural architecture consisted of three or more layers, i.e. input layer H., output layer, and hidden layer, as shown in Fig. 4. The function of this network has been described as follows:

B. Differential Evolutionary (DE)

This control is optimized through the use of a differential evolution technique. The technique uses the power on the load line as an optimization equation to balance its quality and adapt it to fluctuations. The flowchart of the optimization algorithm is shown in the following figure, implemented in MATLAB as equations and adjustment codes to generate an optimized PI output for the dynamic controller.

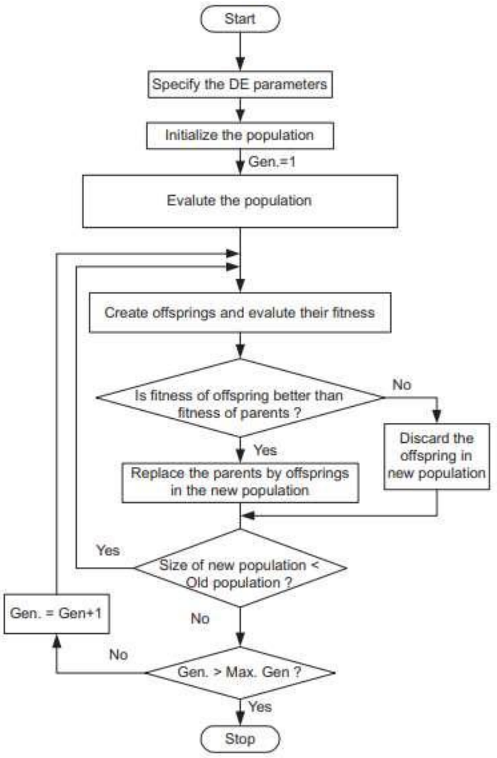

Fig. 6: Flow chart of proposed Differential Evolutionary Algorithm

Differential Evolution (DE) is a population-based heuristic algorithm to solve global optimization problems with different characteristics over continuous space. Despite its simplicity, it proved a great performance in solving non-differentiable, non-continuous and multi-modal optimization problems.

V. SIMULATION RESULTS

MATLAB stands for MATrix LA Boratory, which is a programming package exclusively designed for speedy and effortless logical calculations and Input/output. It has factually hundreds of inbuilt functions for a large form of computations and plenty of toolboxes designed for specific analysis disciplines, as well as statistics, optimization, solution of partial differential equations, information analysis. In this research work MATLAB platform is used to show the implementation or simulation of implemented algorithm performance. Measurement toolboxes are used and some inbuilt functions for generating graphs are used. Simulation results and comparison of the performance of implemented model with some existing ones are calculated by MATLAB functions.

The world is moving from the current centralized generation to a future with a greater proportion of distributed generation. Hybrid energy systems are connected to wind, photovoltaic, and fuel cell energy to generate electricity for local loads and to connect it to grids / micro-grids that reduce dependence on fossil fuels. The hybrid system is a better option for building modern power grids that provide economic, environmental, and social benefits. Work focused on stabilizing grid parameters to integrate these energy resources at various points where heavy loads draw energy from the grid. For this purpose, the two-range test system was used and the analysis is performed in the following cases.

Case 1: Two area system with wind integration with STATCOM without any dynamics controller

Case 2: Two area system with wind-solar integration with neural network and differential evolutionary based forward learning mechanism for system stability enhancement

Case 3: Two area system with wind-solar and Fuel cell integration with neural network and differential evolutionary based forward learning mechanism for system stability enhancement.

Case 1: Two area system with wind integration with STATCOM without any dynamic controller

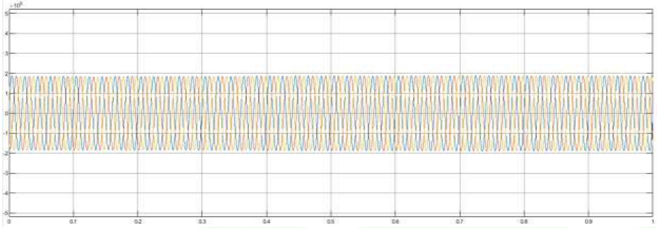

Fig 7: Two area system grid voltage without dynamics controller

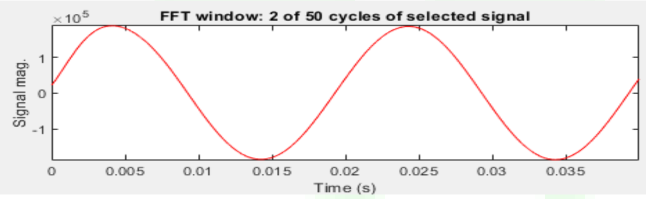

Fig 8: FFT analysis of two area system grid voltage without dynamics controller

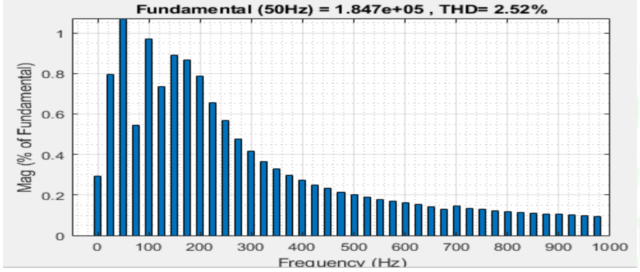

Fig 9: THD % in two area system grid voltage without dynamics controller

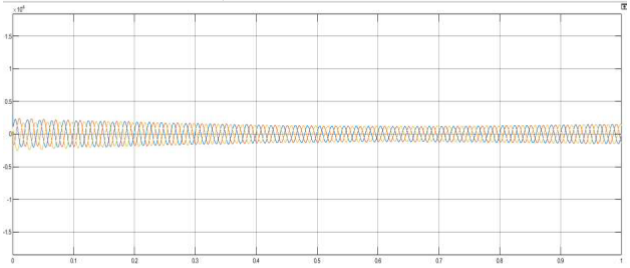

Fig 10: Two area system grid current without dynamics controller

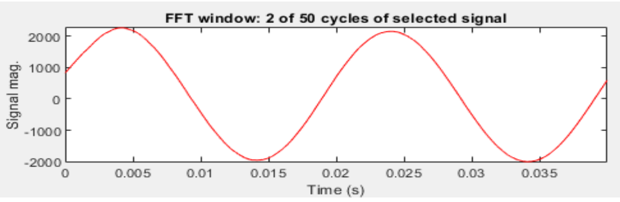

Fig.11: FFT analysis of two area system grid current without dynamics controller

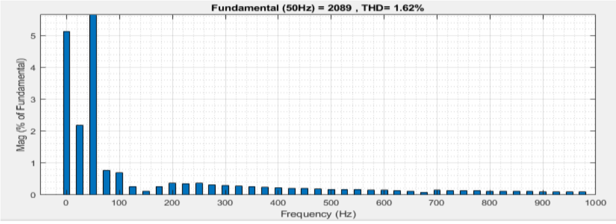

Fig.12: THD % in two area system grid current without dynamics controller

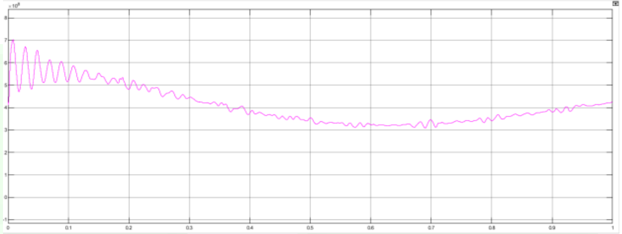

Fig. 13: Active power that can be drawn in two area system grid current without dynamics controller

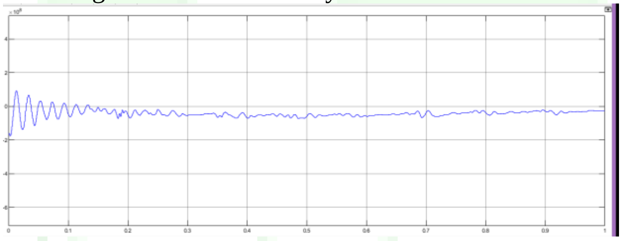

Fig.15: Reactive power in two area system grid current without dynamics controller

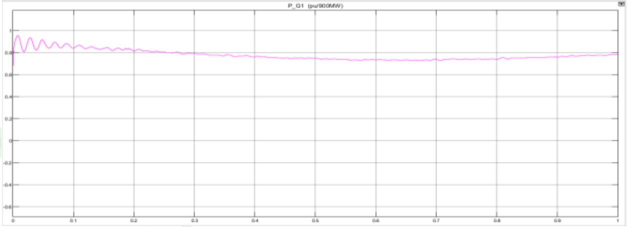

Fig. 16: Power stability in p.u at the generating terminal of machines in case1without controller

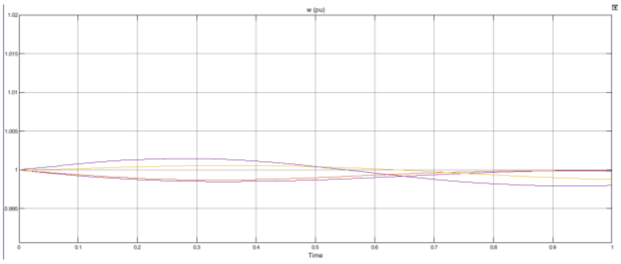

Fig. 17: Rotor Speed variations on wind integration in case1 without controller

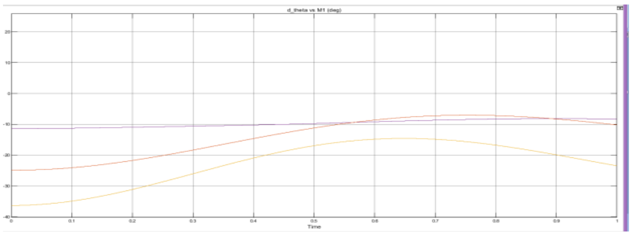

Fig. 18: Rotor Angle Deviation at the machines on integration with wind energy resource in case1

Case 2: Two area systems with wind-solar integration with neural network and differential evolutionary based forward learning mechanism for system stability enhancement.

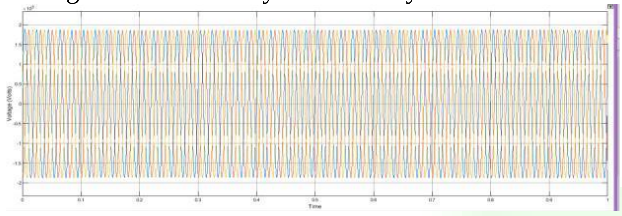

Fig. 19: Voltage at the grid in two area wind-PV integrated system and nn-differential evolutionary control

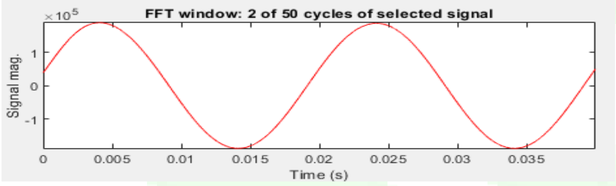

Fig.20: FFT Analysis of voltage at the grid in wind-PV integrated system and nn-differential evolutionary control

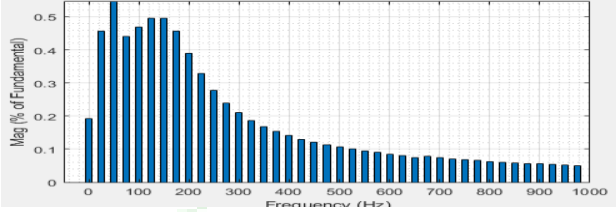

Fig.21: THD% in voltage at the grid in wind-PV integrated system and nn-differential evolutionary control

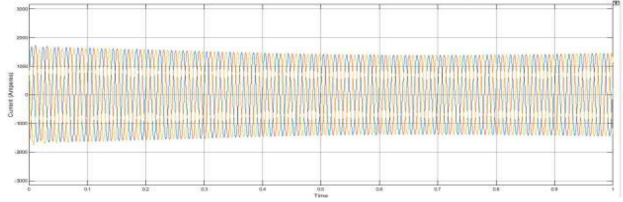

Fig.22: Current at the grid in two area wind-PV integrated system and nn-differential evolutionary control

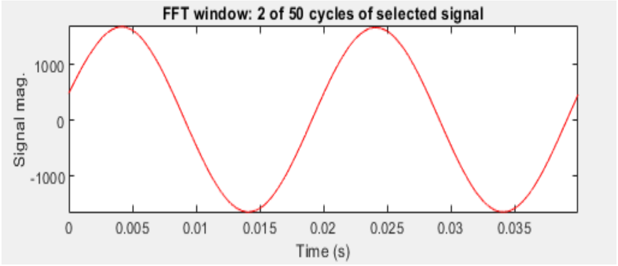

Fig.23: FFT Analysis of current at the grid in wind-PV integrated system and nn-differential evolutionary control

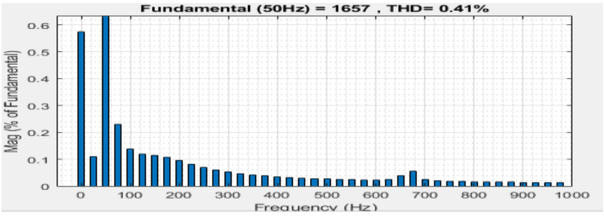

Fig. 24: THD% in current at the grid in wind-PV integrated system and nn-differential evolutionary control

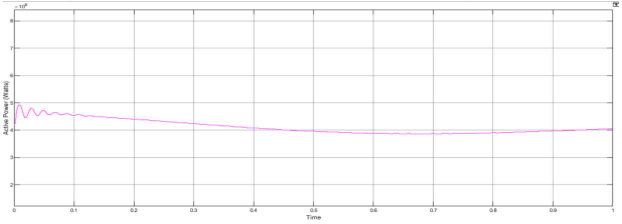

Fig. 25: Active Power at the grid in two area wind-PV integrated system and nn-differential evolutionary control

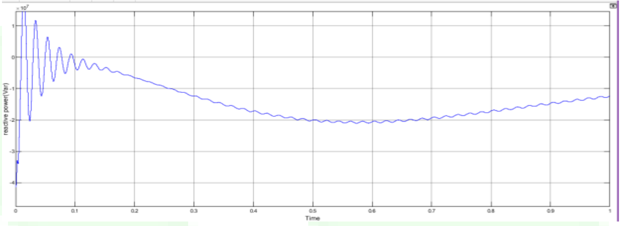

Fig.26: Reactive Power at the grid in two area wind-PV integrated system and nndifferential evolutionary control

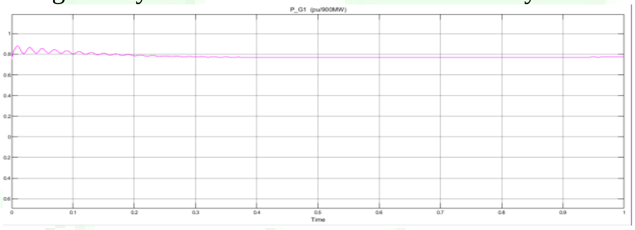

Fig. 27: Power stability in p.u at the generating terminal of machines in case 2

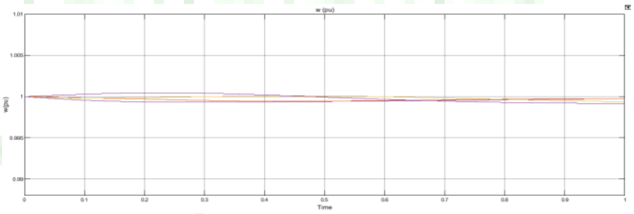

Fig.28: Rotor Speed variations on wind/Solar integration and nn-differential evolutionary control

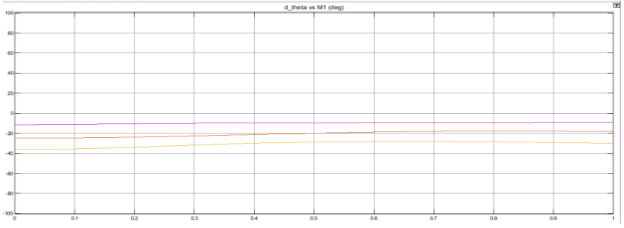

Fig.29: Rotor angle deviation in machines with wind/solar integration and nn-differential evolutionary control

Case 3: Two area system with wind-solar and Fuel cell integration with neural network and differentia evolutionary based forward learning mechanism for system stability enhancement.

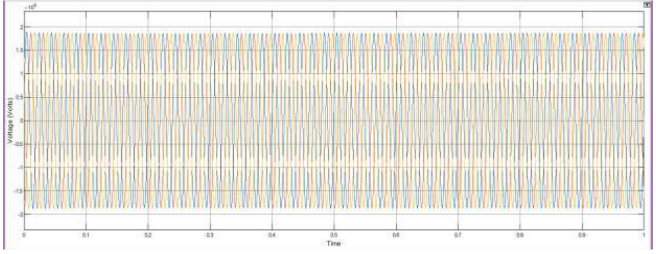

Fig. 30: Voltage at the with wind-PV-FC integrated system in two area and nn-differential evolutionary control

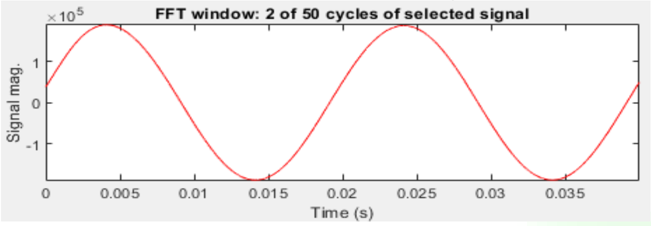

Fig.31: FFT Analysis of voltage a at the with wind-PV-FC integrated system in two area and nn-differential evolutionary control

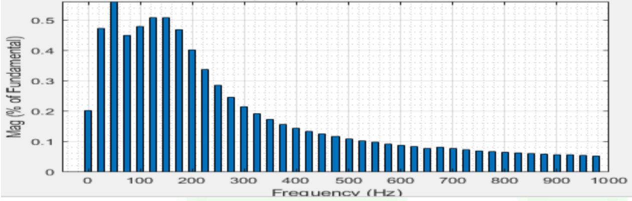

Fig.32: THD% in voltage at the with wind-PV-FC integrated system in two area and nndifferential evolutionary control

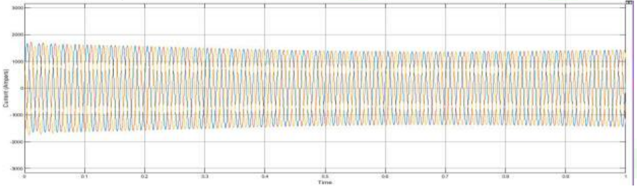

Fig.33: Current at the with wind-PV-FC integrated system in two area and nn-differential evolutionary control

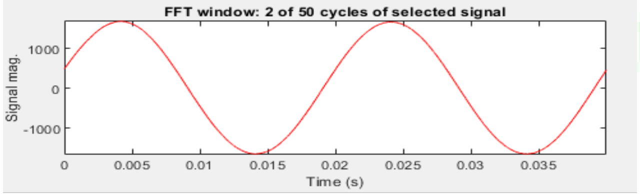

Fig.34: FFT Analysis of current at the with wind-PV-FC integrated system in two area and nn-differential evolutionary control

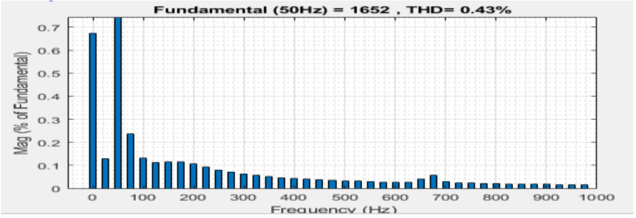

Fig.35: THD% in current at the with wind-PV-FC integrated system in two area and nndifferential evolutionary control

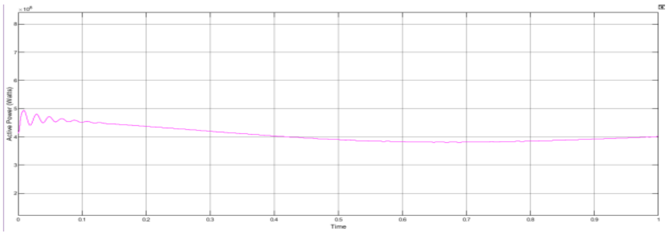

Fig.36: Active power at the with wind-PV-FC integrated system in two area and nndifferential evolutionary control

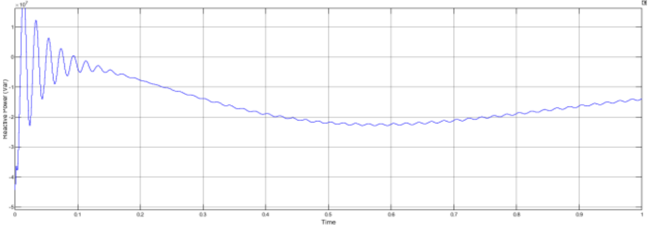

Fig.37: Reactive Power at the with wind-PV-FC integrated system in two area and nndifferential evolutionary control

VI. CONCLUSION

There are several technical problems related to grid-connected systems such as power quality problems, current and voltage fluctuations, storage, protection problems, isolation. Power quality problems are harmonics and voltage and frequency fluctuations. To examine system performance under the influence of renewable energy production units, the Kundur two-line system was used as a test system. Direct integration of these resources was investigated for various instability problems such as rotor angle stability, power stability at the machine generating points, and distortion levels in the grid system waveforms, voltage and current. The work proposed a universal dynamic system optimization control to improve system stability in all aspects, using a differential scalable optimization algorithm based on nn and KI. The MATLAB / SIMULINK environment is the platform for system design and implementation. The effects on the plant with two machines in zone four were studied by integrating a wind plant without dynamic optimization control in zone 1, then plants with sun and wind with a dynamic optimization controller based on differential evolution in zone 2 were developed for heavy loads. The study on the integration of the fuel cell system in zone 1 will also continue.

In order to obtain the best performance from the proposed dynamics controller, the parameters of the system are optimized by subjecting it to a neural network and to an advanced differential evolutionary learning mechanism. The following key conclusions were drawn from the system

The THD% in voltage and THD% in current in final system having wind/solar/FC with proposed neural network and differential evolutionary based forward learning mechanism for system stability enhancement which is considerably reduced than in the system without controller at the time of integration

References

[1] Mohammad JavadMorshed, Afef Fekih “A coordinated control for voltage and transient stability of multi-machine power grids relying on wind energy”, July 2019International Journal of Electrical Power & Energy Systems 109(July 2019):95-109.

[2] Konstantin Schaab, Jannik Hahn “Robust control for voltage and transient stability of power grids relying on wind power”, Control Engineering Practice 60, March 2017.

[3] E. Sharifi, A. H. Mazinan “On transient stability of multi-machine power systems through Takagi–Sugeno fuzzy-based sliding mode control approach”, Complex & Intelligent Systems volume 4, pages171–179(2018).

[4] Kanchanaharuthai, V. Chankong, K. Loparo “Transient Stability and Voltage Regulation in Multimachine Power Systems Vis-à-Vis STATCOM and Battery Energy Storage”, IEEE Transactions on Power Systems, Published 2015.

[5] Schaab K, Hahn J, Wolkov M, Stursberg O (2017) Robust control for voltage and transient stability of power grids relying on wind power. Control Eng Pract 60:7–17

[6] Darabian M, Jalilvand A (2017) A power control strategy to improve power system stability in the presence of wind farms using FACTS devices and predictive control. Int J Electr Power Energy Syst 85:50–66.

[7] Godpromesse K, René F, Hilaire B (2015) An online simplified nonlinear controller for transient stabilization enhancement of DFIG in multi-machine power systems. IEEE Trans Autom Control 60:2464–2469.

[8] Haotian K, Yang L, Wu QH, Xiaoxin Z (2015) Switching excitation controller for enhancement of transient stability of multi-machine power systems. CSEE J Power Energy Syst 1:86–93.

[9] Shi F, Wang J (2012) Stabilising control of multi-machine power systems with transmission losses based on pseudo-generalised Hamiltonian theory. IET Control Theory Appl 6(2):173–181.

[10] Ningqiang J, Hsiao-Dong C (2014) Damping torques of multi-machine power systems during transient behaviors. IEEE Trans Power Syst 29(3):1186–1193.

[11] Son GT, Lee H-J, Lee S-Y, Park J-W (2012) A study on the direct stability analysis of multi-machine power system with resistive SFCL. IEEE Trans Appl Supercond 22(3):5602304.

[12] Casagrande D, Astolfi A, Langarica D, Ortega R (2015) Solution to the multi-machine transient stability problem and simulated validation in realistic scenarios. IET Gener Trans Distrib 8(8):1392–1405.

[13] Wang L, Truong D (2013) Stability enhancement of DFIG-based offshore wind farm fed to a multi-machine system using a STATCOM. IEEE Trans Power Syst 28(3):2882–2889.

[14] K.Karthikeyan, M.Antony Livingston, “Transient Stability Enhancement by Optimal Locality And Fine-Tuning Of Svc Using An Novel Algorithm”, Journal of Xi'an University of Architecture & Technology, Volume XII, Issue V, 2020.

[15] H. Saberi, T. Amraee, C. Zhang, and Z. Y. Dong, “A heuristic benders-decompositionbased algorithm for transient stability constrained optimal power flow,” Electric Power Systems Research, vol. 185, p. 106380, Aug. 2020, doi: 10.1016/j.epsr.2020.106380

[16] K. Yamashita, H. Renner, S. M. Villanueva, G. Lammert, P. Aristidou, J. C. Martins, L. -

[17] Z. Zhu, L. D. P. Ospina, and T. V. Cutsem, “Industrial recommendation of modeling of inverter-based generators for power system dynamic studies with focus on photovoltaic,” IEEE Power and Energy Technology Systems Journal, vol. 5, no. 1, pp. 1–10, Mar. 2018.

[18] A. M. Khalil and R. Iravani, “Enhanced generic nonlinear and linearized models of wind power plants,” IEEE Transactions on Power Systems, vol. 32, no. 5, pp. 3968–3980, Sep. 2017.

[19] G. Shahgholian, "Power system stabilizer application for load frequency control in hydroelectric power plant", Engineering Mathematics, 2, No. 1, pp. 21-30, Feb. 2017.

[20] T. Fetouh, M.S. Zaky, "New approach to design SVC-based stabilizer using genetic algorithm and rough set theory", IET Gen., Trans. and Dist., 11, No. 2, pp. 372-382, Jan. 2017.

[21] O. G ¨ oksu, M. Altin, J. Fortmann, and P. Sørensen, “Field validation of ¨ IEC 61400-27- 1 wind generation Type 3 model with plant power factor controller,” IEEE Transactions on Energy Conversion, vol. 31, no. 3, pp. 1170–1178, Sep. 2016.