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Comparative Analysis on Soft Computing Based Wind Farm Model

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***Abstract*: This paper presents the importance of soft computing techniques in Wind Generation System. Since wind speeds typically vary over a wide range, the turbine speed needs to be continuously adjusted so that its power output can be maximized and also it usually leads to better result than those of the conventional controllers. Many researchers have studied and performed the simulations in wind generation system using different soft computing technique. The purpose of the study is to do comparisons of various soft computing techniques used for improvement of wind form model. In wind generation system different techniques like particle swarm optimization, generalized regression neural network (GRNN), fuzzy logic control, genetic algorithm, mean variance optimization algorithm etc. has been used for efficiency optimization and performance enhancement control. The characteristics and merits of these techniques on wind form model is then compared and studied. After studying the different soft computing technique it is found that a system using the fuzzy controller based amongst the other soft computing techniques shows more accurate control performances.**

***Keywords:* Doubly fed induction generator, direct power control, grid side converter, rotor side converter, particle swarm optimization, fuzzy lozzy controller.**

I. INTRODUCTION

The amount of renewable electricity harnessed from the wind is growing rapidly. Wind generation system is the best amongst all the other renewable energy sources in the world. Power generated from wind energy system is cheaper and it is also competitive with fossil fuel.

Electrical power generation from wind energy system began to gain attention from the beginning of this century. Wind power has been seriously considered to supplement the power generation by fossil fuel and nuclear methods. Nowadays wind power is gaining more popularity because of environmental friendly nature of wind generation system.

Reddy, et.al. in his research paper discussed the performance of the wind generation system has improved significantly compare to the conventional PI controller by choosing appropriate fuzzy rules that are designed to tunes the parameters of conventional PI controller. In this paper three fuzzy logic controllers has been used which shows the significant increase in output power of the wind generation system compare to the conventional PI controller. [1]

Hagh, *et.al*. has proposed that the wind turbine is directly coupled to the grid as the power delivered by wind turbines is not constant because of the variability of the wind. But still, wind turbine generators should have the ability to determine and extract the maximum possible mechanical power from the wind and converting it into electrical power.

A function of wind speed is used to determine the maximum absorbable power and thereby wind speed is estimated using a generalized regression neural network (GRNN).Simulation results on 660-kW grid-connected DFIG is provided which shows the effective results on tracking maximum power in presence machine parameters variation.[2]

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Jeba V, et.al. presented the optimum design method for the coordinated tuning of rotor side converter (RSC) and grid side converter (GSC) controllers of grid-connected doubly fed induction generator (DFIG) wind turbine system. These coordinated tuning of RSC and GSC controllers are estimated to optimize the performance parameter. The optimization is performed using particle swarm optimization (PSO) on a multi objective optimal controller design of a DFIG wind turbine system. The effectiveness of the designed parameters using PSO is then compared with that obtained using simulated annealing (SA).[3]

Barambones, et.al. in his paper discussed about the proposed variable structure control has an integral sliding surface in order to relax the requirement of the acceleration signal, that is usual in conventional sliding mode speed control schemes. The reference speed of optimal wind turbine is tracked by a suitable speed controller. In this work, an adaptive robust control is used to maximizing the power generation of a variable speed wind turbine. The proposed robust control law show a good result under wind turbine system uncertainties and the control law is based on a sliding control theory.[4]

Xu, et.al. has discussed the wind turbine control during strong and gusty winds with speed change can lead to large loads on the turbine and unnecessary turbine shut-downs by the supervisory system due to rotor over speeds. This can't be efficiently accomplished by classical wind turbine control system.

A Combined use of generator electromagnetic torque and pitch control, approach is used and also a ripple torque technique is used to increase the drive train damper to avoid gearbox vibration. Thereby it provides simulation result on different control schemes and this approach is capable of preventing rotor over speed and can also reduce loads of drivetrain.[5]

Dumnic, et.al. in his paper presented the combination of Genetic Algorithm, Partical Swarm Optimization and Simulated Annealing is used to optimize Proportional integral controller in the Model Reference Adaptive System(MRAS) observer and comparative analyses of the optimal speed estimation of induction generator is also presented. Through the simulation in Matlab/Simulink the performance of sensorless controlled variable speed of wind turbine is evaluated.[6]

Kahrobaee, et.al. has proposed that, to reduce dependence on fossil fuels and minimize greenhouse gas emission an integration of increasingly available renewable energy sources, such as wind energy, into the power grid is used to perform the desired action. Balancing of generation and load becomes very difficult due to stochastic nature of renewable generation. In promoting the development of renewable energy for fulfilling the high demand for electricity, storage of energy plays the important role.

Here a wind generation Compressed Air Energy Storage (CAES) system is proposed, it can generate, store, and sell electricity to the grid. To optimize the short-term operation and long-term planning, two optimization methods are used which is based on particle swarm optimization (PSO). The aim is to estimate the optimum capacities of these resources as well as the optimum day-to-day operation strategy in order to achieve maximum profit. The profitability of the wind generation-CAES system includes market price, wind speed, gas price, etc. Many sensitivity analyses are performed to determine profitability and the impact of different factors on the results.[7]

Sim6es, et.al. in his paper discussed that a fuzzy controller tracks the generator speed with the wind velocity to extract the maximum power. Maximum power is extracted from generation system using the fuzzy controller. Thereby for light load efficiency improvement, a second fuzzy controller is used which programs the machine flux and turbine oscillatory torque is estimated through the third fuzzy controller. All the system parameter is evaluated in detail after simulation.[8]

Mokhtari, et.al. in his paper discussed that wind farms are located very far from the generation system. Therefore it results in oscillation of local signals and it do not comprise enough content for damping inter-area oscillations. The particle swarm optimization (PSO)-based wide-area damping controller (WADC) for the DFIG wind farms is used to perform the optimization. The proposed controller is designed with the intention of damping both inner-area and local oscillatory modes. The PSO technique is proposed to optimize the parameters of the generation system.[9]

According to Qiao, et.al. there are Several ongoing research in the area of the application of computational intelligence (CI) for control of wind turbine generators. Such control strategies including mean-variance optimization (MVO) algorithm for wind plants are presented for the enhancement of wind turbine generators and the associated power grid. The searching space within the mean-variance optimization algorithm is restricted to the range - zero to one - which does not change after applying the transformation. The features of MVO make it a potentially an attractive algorithm for solving many real-world optimization problems such as the tuning of PI controllers on a DFIG.[10]

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II. WIND FARM MODEL

The global electrical energy consumption is rising and there is steady increase of the demand on power generation. The existing conventional energy sources are depleting. So alternative energy source investment are becoming more important now days.

Wind electrical generation systems are recently getting lot of attention, because they are most cost competitive, environmental clean and safe renewable power source, as compared to fossil fuel and nuclear.

The wind generation system is that the most cost competitive of all the environmentally clean and safe renewable energy sources within the world. It is additionally competitive with fuel generated power and far cheaper than atomic energy. Though the history of alternative energy goes back quite two centuries, it's potential to generate electrical power began to get attention from the start of this century. However, through the last 20 years, wind generation has been seriously thought of to supplement the power generation by fossil fuel and nuclear strategies.

In recent years wind generation is gaining additional acceptance owing to environmental and safety issues of typical power plants and advancement of wind electrical generation technology, the world has enormous resources of wind generation.

The control algorithm applied in wind generation system tracks the maximum power output from wind turbine that varies nonlinearly with wind speed. So for maximum power output, wind turbine need to be adjusted continuously. It also reduces the machine rotor flux from the rated value which reduces core loss to the great extent and thereby increases machine-converter system efficiency.

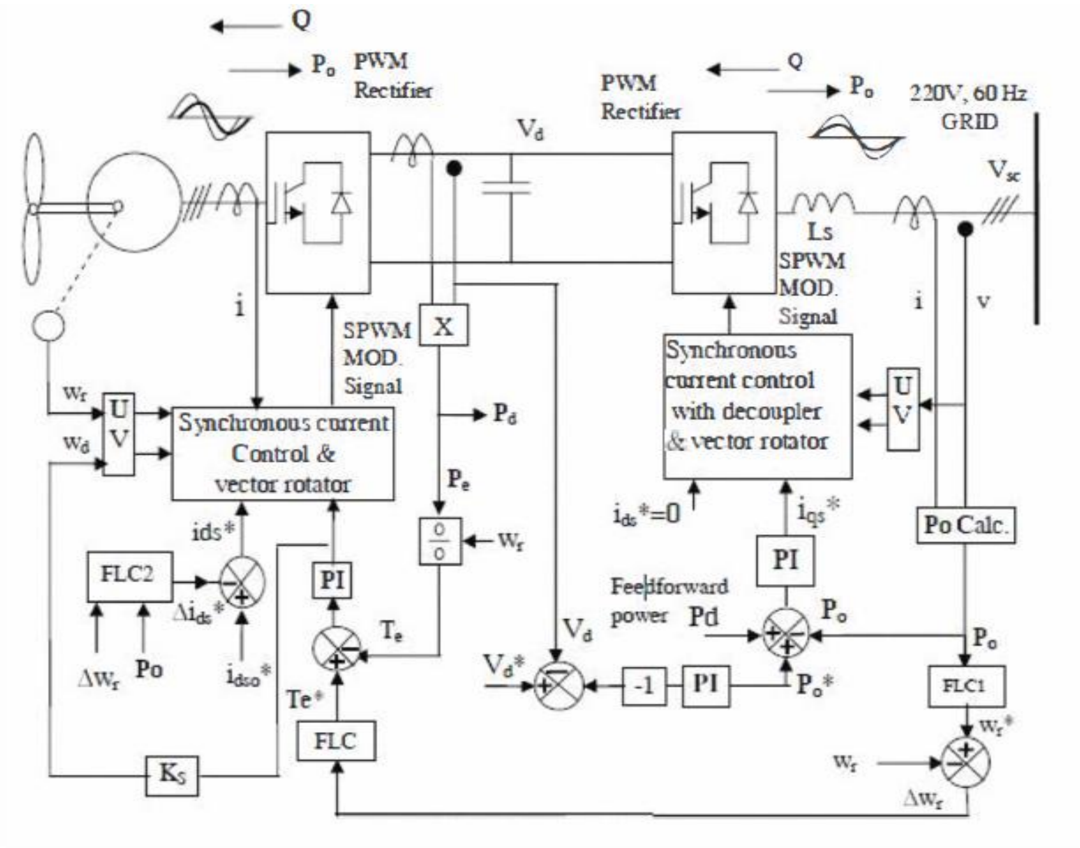

Figure.1: FUZZY logic based control block diagram of wind generation system[1]

III. BRIEF DESCRIPTION ABOUT THE TECHNIQUES

Various strategies are already done in this field of wind generation system in order to achieve efficiency optimization performance enhancement control. The following control schemes are illustrated below.

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A. Particle swarm optimization (PSO) & Generalized Regression Neural Network:

Here wind speed is determined using generalized regression neural network (GRNN) and a function of wind speed is used to estimate online maximum absorbable power. After this a nonlinear robust sliding mode control(SMC) scheme employed by a proposed Direct Power control(DPC) strategy is used to calculate the required rotor control voltage directly and there by inertial weights is estimated by incorporating the concept of sliding mode control(SMC) into particle swarm optimization. The new DPC based on SMC-PSO scheme has acceptable harmonic spectra of stator current by using space vector modulation (SVM) block with constant switching frequency. Simulation results on 660-kw grid connected DFIG are provided and show the effectiveness of the new technique, for tracking maximum power in presence machine parameters variation.[2]

B. Adaptive Robust Control:

The reference speed of optimal wind turbine is tracked by a suitable speed controller. In this work an adaptive robust control is used to maximizing the power generation of a variable speed wind turbine. The proposed robust control law show a good result under wind turbine system uncertainties and the control law is based on a sliding control theory.[4]

C. Genetic Algorithm, Partical Swarm Optimization and Simulated Annealing:

Genetic Algorithm, Partical Swarm Optimization and Simulated Annealing is used to optimize Proportional integral controller in the Model Reference Adaptive System(MRAS) observer and comparative analyze of the optimal speed estimation of induction generator is also presented. Through the simulation in Matlab/Simulink the performance of sensorless controlled variable speed of wind turbine is evaluated. [6]

D. Mean Variance Optimization Algorithm:

There are Several ongoing research in the area of the application of computational intelligence (CI) for control of wind turbine generators. Such control strategies including mean-variance optimization (MVO) algorithm for wind plants are presented for the enhancement of wind turbine generators and the associated power grid. The searching space within the mean-variance optimization algorithm is restricted to the range - zero to one - which does not change after applying the transformation. The features of MVO make it a potentially an attractive algorithm for solving many real-world optimization problems such as the tuning of PI controllers on a DFIG. [10]

E. Fuzzy Loggy Controller:

The fuzzy logic controller is a complex control system that analyzes difficult simulated problems with logical inputs and output variables.

The output state of the fuzzy logic control system is obtained in the form of recommendation for a particular interval. Thereby it becomes necessary that mathematical calculation for the fuzzy logic control system should be done very strictly from the more known logic, such as Boolean algebra.

Here wind generation system uses Fuzzy logic Controller to extract maximum power output by tracking the generator speed with wind velocity. And also it is able to improve the light load efficiency by programming the machine flux. The other uses where the fuzzy logic controller has been used to provide robust speed control against wind vortex and turbine oscillatory torque.[1]

IV. RESULT

According to M. T. Hagh, a generalized regression neural network (GRNN) is used to determine wind speed (fig.2) as it's well known that in wind generation system the wind speed is not constant and besides that maximum absorbable power is estimated online as a function of wind speed. And also a DPC based on SMC-PSO scheme has acceptable harmonic spectra of stator current by using space vector modulation (SVM) block with constant switching frequency. Simulation results on 660-kw grid connected DFIG are provided and show the effectiveness of the new technique, for tracking maximum power in presence machine parameters variation.

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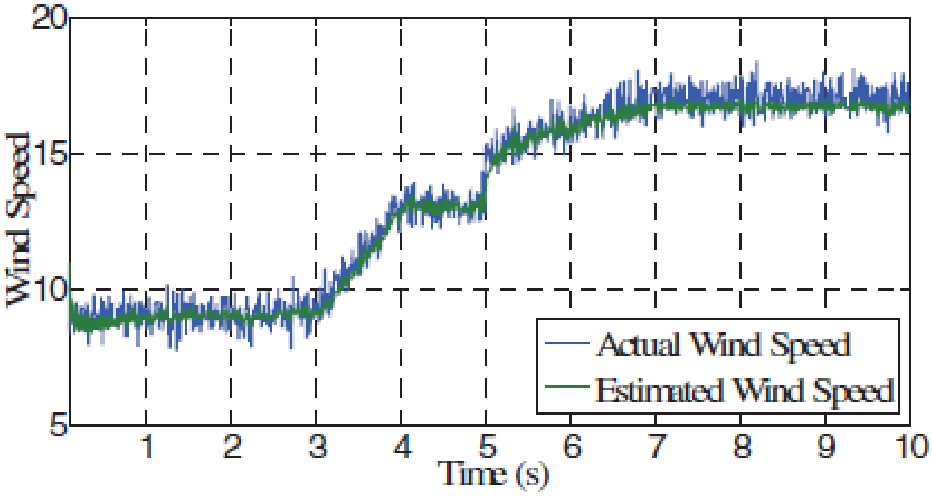

Fig 2: Actual and estimated wind speed

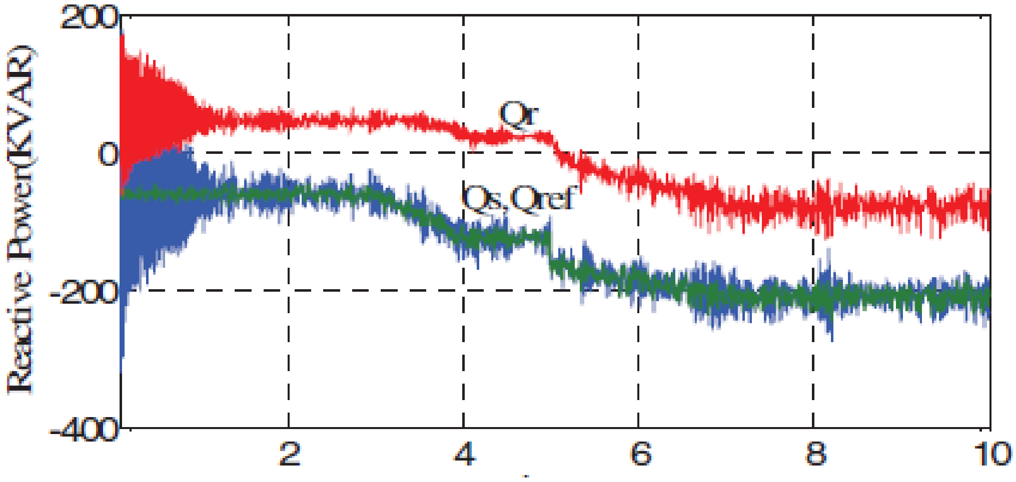

Fig 3: Stator active power time response in proposed SMC DPC & PSO

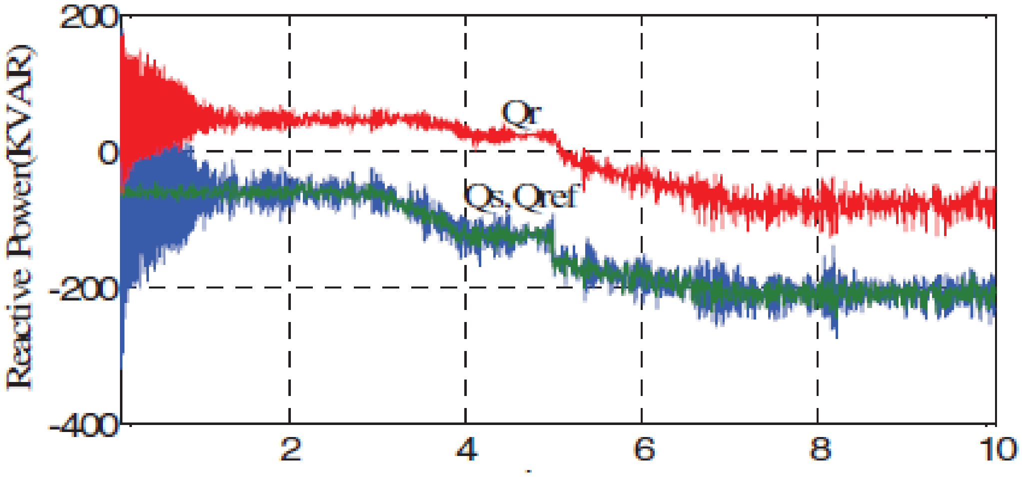

Fig 4: Stator reactive power time response in proposed SMC DPC & PSO

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F. According Oscar Barambones, an adaptive robust control is used to maximizing the power generation of a variable speed wind turbine. The proposed robust control law show a good result under wind turbine system uncertainties and the control law is based on a sliding control theory.

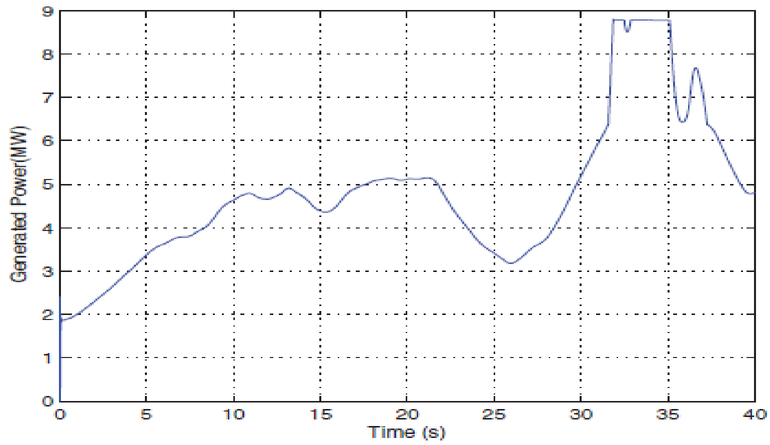

Fig 5: Generated Active Power

C: According to Boris Dumnic, the rotational speed of the induction generator is determined through a combination of Genetic Algorithm, Partical Swarm Optimization and Simulated Annealing. Here an induction generator in a variable speed wind energy conversion system has been used with MRAS observer to estimate the desired result.

D. According to Wei Qiao, A control strategies including mean-variance optimization (MVO) algorithm for wind plants are presented for the enhancement of wind turbine generators and the associated power grid. This paper has used DFIG wind turbines as an example to show the WTG control and integration improvement obtained from CI techniques. Similar

Approaches can be applied to other types of WTGs.[10]

E. According to M. Godoy Simoes, Here wind generation system uses Fuzzy logic Controller to extract maximum power output by tracking the generator speed with wind velocity. And also it is able to improve the light load efficiency by programming the machine flux.

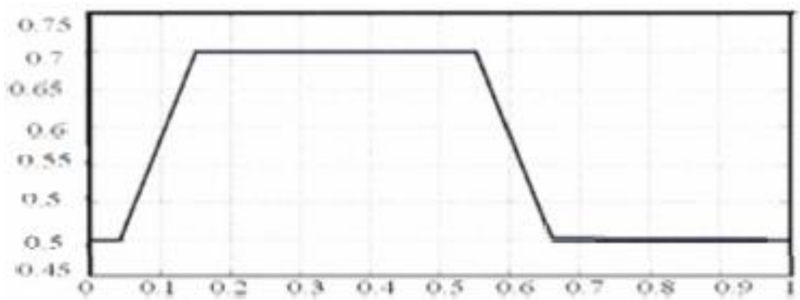

Fig: 6 Wind velocity-time(in sec)

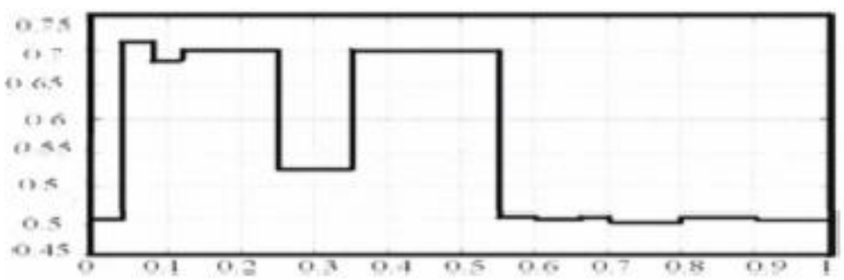

Fig: 7 Flux current-time(in sec)

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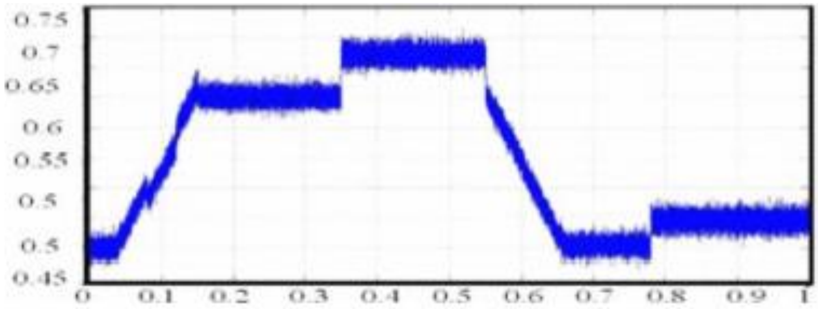

Fig: 8 Output power-time (in sec)

V. CONCLUSION

The wind generation system is analyzed and designed, through various techniques and performances were studied extensively. Results of the referred techniques proved that fuzzy logic controller based wind generation system performance is good. And it is parameter insensitive, the robustness, provides fast convergence, and accepts noisy and inaccurate signals. System performance, both in steady state and dynamic conditions was found to be excellent. If it is compared with P I controller, system efficiency is high.

After studying the different soft computing technique we have found that a system using the proposed fuzzy controller show more accurate control performance and faster dynamic response with almost no steady state error when compared to a system using conventional controller. As future work, will need to perform more experiments using different membership functions of fuzzy systems and will do empirical evaluation study for the proper selection of membership function during the fuzzy logic design in wind generation system.

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