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# Simulation and Analysis of Integrated Wind Power with Small Hydroelectric Hybrid Power System for Transient Stability

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*Abstract:* **A hydroelectric power plant produces enough electrical power which is sufficient for utilizing. But when transmission is done, than because of transmission constraints it is not possible to use full generated power. As population is increasing, so in past years due to increase in population the consumption of electrical power is going up day by day. This is resulting in to the burden on the transient stability limits of the power generation systems. So integrating wind power generation with small hydroelectric power plant, comprising a hybrid hydroelectric power plant and wind power plant is the transient stability of the hybrid power system can be analyzed for solving aforesaid problems. As from previous studies it has been analyzed that by the integration of renewable energy source into desired and weak locations of the grid, the stability can be increased. This paper is the investigation about wind power integration with small hydroelectric power plants. And when two or more than two power systems are combined, the resulting power system is known as hybrid power system. In this research work the investigation of small hydroelectric and wind hybrid power system (HWHPS) is done for obtaining the model characteristics in order to reduce stress on the transient stability. This research work is based on the model developed and simulated through Sim Power System simulation software in MATLAB.**

*Keywords:* **Integrated energy system, Hybrid power generation, renewable energy generation, Sim Power System.**

## 1. INTRODUCTION

In India energy consumption in the development of the domestic, agriculture, industrial societies and for other basic needs is increasing day by day to a high level in order to achieve a perfect living. Due to increase in the use of electrical energy generation in various power systems is also increasing, resulting into emission of the green house gas which is polluting the atmosphere and climate [1]. Since there are different type of power systems which are being used for generation of electrical energy but hybrid power systems are the best approaches for electrifying the rural areas and communities of India [2]. These different power systems are solar photovoltaic cells, wind energy, hydroelectric power, thermal power, nuclear power, wave and tidal energy etc, but this paper is representing the investigation about the wind power integration with the small hydroelectric power plants. So when two or more than two power generating systems are combined than they are called hybrid power systems. When two or more than two power systems are interconnected the consumption of electrical energy and demand at the peak load can be achieved, this ensures the better quality of electrical energy. And will also decrease the production of the green house emission and conventional energy when fossil fuels are burned for the generation of the electricity [3]. A hydroelectric power plant produces enough electrical power which is sufficient for utilizing. But when transmission is done, than because of transmission constraints it is not possible to use full generated power. As population is increasing, so in past years due to increase in population the consumption of electrical power is going up day by day. This is resulting in to the burden on the transient stability limits of the power generation systems. So by integrating wind power with small hydroelectric power plant, comprising a hybrid hydroelectric power plant and wind power plant the transient stability of the hybrid power system can be analyzed for solving aforesaid problems. Though availability of wind power is not continuous so hydroelectric power plants are used for reserving energy in the form of water in reservoir. Water can be released when there is need to generate electricity. This paper is the investigation about wind power integration with the small hydroelectric power plants. And when two or more than two power systems are combined, the resulting power system is known as hybrid power system. In this dissertation the investigation of small hydroelectric and wind hybrid power system is done for obtaining the model characteristics in order to reduce stress on the transient stability. This paper is based on the model developed and simulated through SPS simulation software in MATLAB.

## 2. LITRATURE REVIEW

A better method of integrated wind power with hydro and thermal power plants is presented in this reference paper. For the future works author has proposed that this approach can be easily applied in the analysis of other renewable energy source for integration capacity with pumped hydro storage power stations [4]. As hydroelectric stations in some power system

are unable to fulfill the demand supply at peak loads therefore wind power integration is considered to supply so that it can partially meet the consumers demand. An analysis of combined operation of power station like wind power and hydro power stations with thermal power station is done for effective results. For further studies author recommends the factors considering the condition of multiple hydro and wind power systems from the grid point of view [5]. The benefits of reliability by the coordination of hydro power plant and wind power to increase the load carrying capability are shown. In future wind and hydro coordination could be extended to analyze the reliability of wind power linked with systems like pumped storage large scale batteries etc [6].

A investigation on the isolated wind hydro hybrid system with the permanent magnet synchronous generator operated by a wind turbine of varying speed supplying three phase load and a squirrel cage induction generator is done. The performance of the predicted hybrid power system is shown resulting in conclusion that a hybrid power system performance under these conditions is satisfactory with the constant value of voltage and frequency [7]. A maximized wind penetration in wind hydro pumped storage for finding an alternate solution to develop power as conventional generation unit is presented. In future operation efficiency should be found and investigation on the optimal design and system performance should be done [8].

For studying the implementation of the technique regarding hybrid hydro power plants is presented in this paper. To analyze the hybrid wind hydro power plants HIDROEOL didactic stand is under construction and for the future the author has proposed that the work that is being done by the author can be used for studying wind power integration in a hybrid power system [9]. The investigation on the hybrid power system is done, which was designed in PSCAD software. Different characteristics of the hybrid power system were observed for finding that the voltage stability and automatic load sharing capacity is provided by the hybrid power system. To increase the supply services to the rural communities a technological approach is presented in this paper [10]. An optimization technique for the hybrid energy system for rural communities in India is presented. *Different forms of costs were obtained such as energy cost for various sources, capital cost, and Hybrid power system's optimized cost. When two or more than two renewable sources are combined in order to form Hybrid power system, then a better stability and efficient power supply is obtained [11].* In Indian condition a combination of wind and hydro power plant is done in order to penetrate the Renewable energy source in India by reducing the cost of electrical power. In the conclusion it was shown that the combination of wind and hydro power plant results into an efficient operation of Hybrid power system [12]. A representation of designing and simulation of small wind and hydro plants is done. This paper explains about the future scopes of studying the wind power integration in an electrical power system [1]. Author has shown an optimal control of sources and loads so as to obtain power synchronism in between generation and consumption. To maintain reactive power compensation a static VAR compensation is used considering the transient and dynamic behavior of the system. For future author has explained that the dynamic mechanical and electrical characteristics should be analyzed to obtain the effect of transients on the frequency and voltage regulation [13]. A dynamic impact of hybrid wind/pv/small hydro power on the transient stability is presented in this paper. Author have observed system by using oscillations duration and critical clearing time and represented that with increased number of generators burden on the power system also increases [14]. A hybrid power system is developed by combining various conventional and non conventional power sources, for reducing green house emission from the consumption of fossil fuels and to increase the stability of the power system so that a reliable operation of electricity is gained. And for the future it is proposed that configuration of the system can be implemented for designing of the power systems in order to achieve stability and reliability [3]. A hybrid energy system consisting of wind power, photovoltaic, biomass and small hydropower is designed for continuous power supply.

The author in this paper has summarized the existing system in order to show calculations for the advantages and disadvantages of the coordination of the wind and hydropower system. In this paper futures recommendations are like profit maximization, transmission improvement and balance power generation [15]. An investigation of continuous power supply is done for obtaining the operation and control strategies of hydro-wind hybrid power system. Results are obtained in order to maintain both voltage and frequency within needed levels with optimum settings of the parameter [16]. For better voltage regulation and for an efficient transient stability, a STATCOM is connected to the power system which is controlled by a method known as PQ technique. A technique of STATCOM control helped in achieving the steady state torque and steady state speed [17]. Modeling of diesel, wind farm, a pumped storage hydro plant is done and simulation is done in the software named as PSS/E. After the disturbances the analysis of transient stability is done in the model [18]. Analysis of transient stability performance of three generator and nine bus hybrid power system has been presented. Hybrid power system consists of a small hydro power unit and two steam power units. A technique of braking resistor control and fast valve is presented in order to improve the transient stability of the hybrid power systems containing three generating units i.e. two steam and one hydro unit. Fault clearing time and rotor angle characteristics were analyzed in order to observe transient stability [19].

## 3. HYBRID POWER SYSTEM AND TRANSIENT STABILITY

### *3.1 Hybrid power systems*

A hybrid power system (HPS) is the combination of two or more than two energy generating sources like solar

photovoltaic cells, wind energy, hydroelectric power, thermal power, nuclear power etc [3]. HPS may or may not be in connection with the grid; therefore they usually are not dependent on centralized grids and can be used in rural places [20]. As the proposed work is the investigation of small hydroelectric power and wind power, therefore only these two are considered here for the hybrid power system. A Block diagram of the hybrid hydroelectric and wind power system for this research work is shown below in the figure 3.1

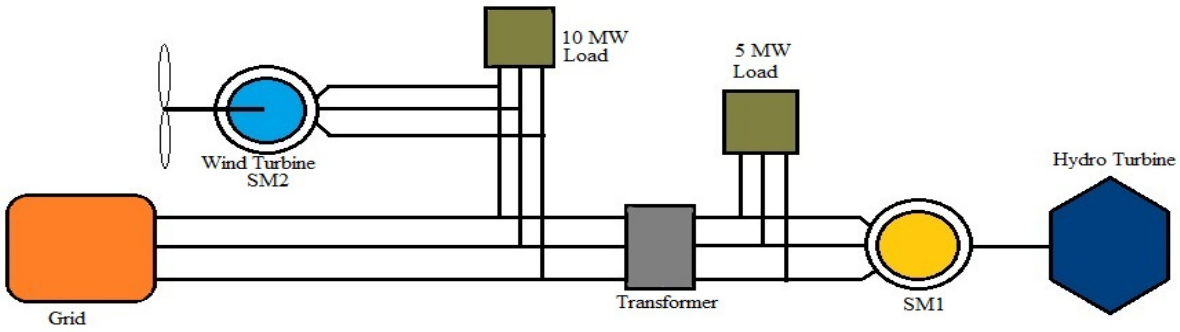


**Figure 3.1 – Hydroelectric and wind hybrid power system**

### *3.2 Introduction to stability*

#### *3.2.1 Power system stability*

Power system stability (PSP) may be defined as the characteristic of the system to regain its equilibrium after sudden disturbances. A typical representation of PSP is shown in the figure 3.2.1. When synchronous machines are operated in parallel then power system transients are introduced and with long distance transmission it becomes important phenomenon [21].

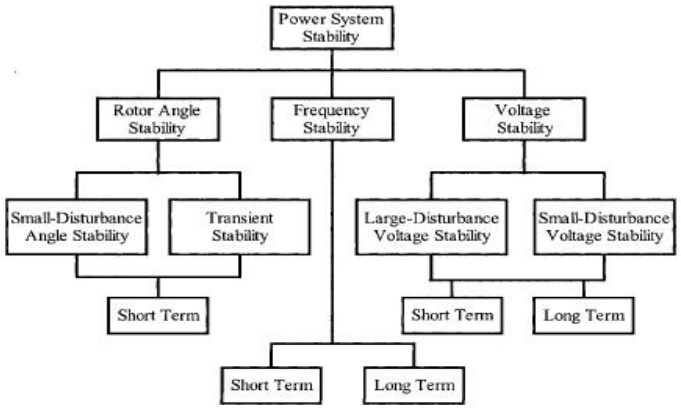


**Figure3.2.1 Types of power system stability**

#### *3.2.2 Transient stability*

When in a power system there are large disturbances than the ability of power system to maintain the synchronous operation and torque balance of the machines is known as transient stability. The system usually goes into transient state if a fault occurs or the disturbances are larger. In first swing transients the study involves a time space which is not more than one second. There is possibility of staying transient stable only if machine has same and stable operation in the first second whenever system is subjected to disturbances. But if that disturbance is occurring for more period or more than one second than there is need of a multi swing study of hydraulic turbine governor HTG controls.

## 4. PROBLEM FORMULATION

By the detailed literature review analysis it was found that the work that is to be done in this research work has complimented the objectives. The load of 5MW is considered, which is fed up by the small hydroelectric plant. Let us assume that there is increase in the load following by 10 MW at far distance from the SHEP. So in that area for feeding load a new transmission line must be installed. But an alternative solution is to build a wind power system for generation so as to supply the increased power demand by the integration operation of the small hydroelectric and wind power generation, by stabilizing the transient stability of the hybrid power system. The investigation about the wind power integration with the small hydroelectric power plants will be presented. The proposed model will be developed and simulated through power system simulation software in MATLAB for obtaining the model characteristics in order to reduce stress on the transient stability. And if the power out of the entire system is to be calculated than following equations can be used.

**Hydro turbine calculations:**

$P_h = g\ \rho\ WH$ units are Watts

Where W = water discharge through the turbine in m/s, ρ = Density (kg/ m), H = Head (m), G = 9.8 $m/s^2$

Therefore, Power:

**$P_h = 9.8WH$** units are kW

Total potential of the water can be calculated from following formula: $\mathbf{P_{total} = P_h \times n_t \times n_g}$

Where $P_h$ = Hydraulic power, $n_t$ = Turbine efficiency, $n_g$ = Generator efficiency

**Calculation for $P_h$:**

$$P_h = P_e \times e_w \times g \times h_f$$

Where $P_e$ = Coefficient of electrical discharge, $e_w$ = Water density, g = Gravitational acceleration, $h_f$ = Water head

**Wind turbine calculations:**

$P_w = KV^3\ W/m^2$ Where the value of K = $1.3687 \times 10^{-2}$

Therefore; $P_w = 0.5\rho Av^3 W$

Where ρ = Air density (1201 g/$m^3$ at NTP), V = Wind speed (Km/h), A = Swept area ($m^2$)

## 5. SIMULATION

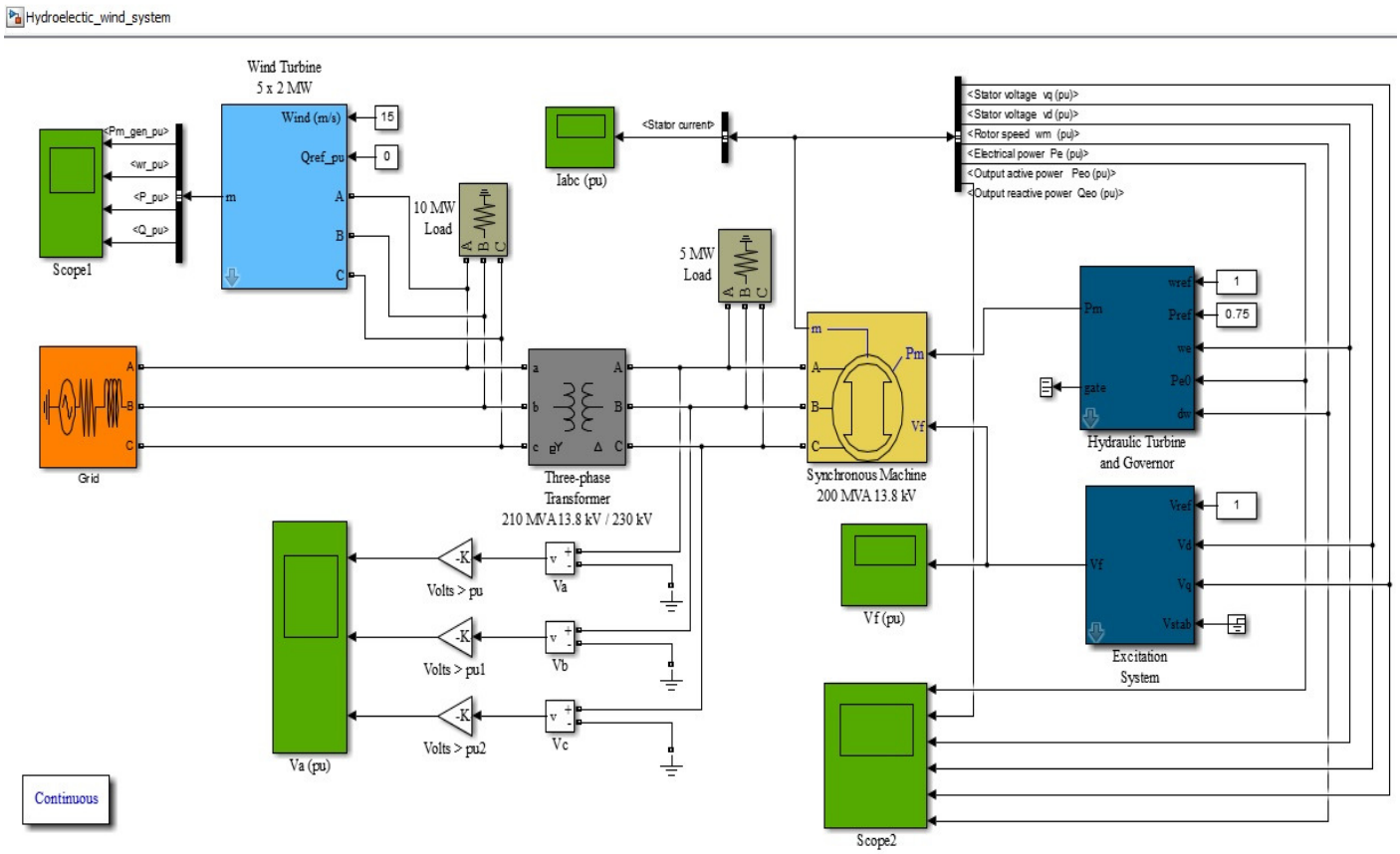


**Figure 5.1 Simulated model of hydroelectric and wind power plant**

In the shown figure 5.1 the load of 5MW is considered, which is fed up by the small hydroelectric power plant. There is increase in the load following by 10 MW at some distance from the SHEP. So in that area for feeding load a new transmission line must be installed. But an alternative solution is to build a wind power system for generation so as to supply the increased power demand by the integration of the small hydroelectric and wind power generation, by stabilizing the transient stability of the system. A SM of 200 MVA, 13.8kV and a three phase transformer of 210 MVA 13.8 kV/ 230kV is connected in between HTG, excitation system, loads and grid.

## 6. RESULTS AND DISCUSSION

**6.1 Case I characteristics without integrating wind turbine:** Iabc are the characteristics for the stator current. Scope2 represents the characteristics for the HTG. Vf are the characteristics for the excitation system. Va represents the phase voltages. Iabc, Va, Vf and scope2 characteristics are represented in the figure 6.1.

***Discussion***

In case I when the both load 5MW and 10MW load is fed by the hydroelectric power system the stator current shown in figure 6.1 and the phase voltage shown in figure 6.1 are not linear and are also not constant. They are also not in a phase with respect to stability of the system. And the characteristics shown in figure 6.1 of the hydraulic turbine and governor from which it was analyzed that the output active Peo and reactive power Qeo, stator voltage Vd and Vq, electrical power Pe are not uniform and are varying simultaneously which results into

a unstable state. The excitations provided by the excitation system are also irregular and not uniform which results into non stability of the system. The excitation characteristics Vf are also shown in the figure 6.1 and the rotor speed Wm in pu is also not uniform by which it can be predicted that this system is not a transient stable system.

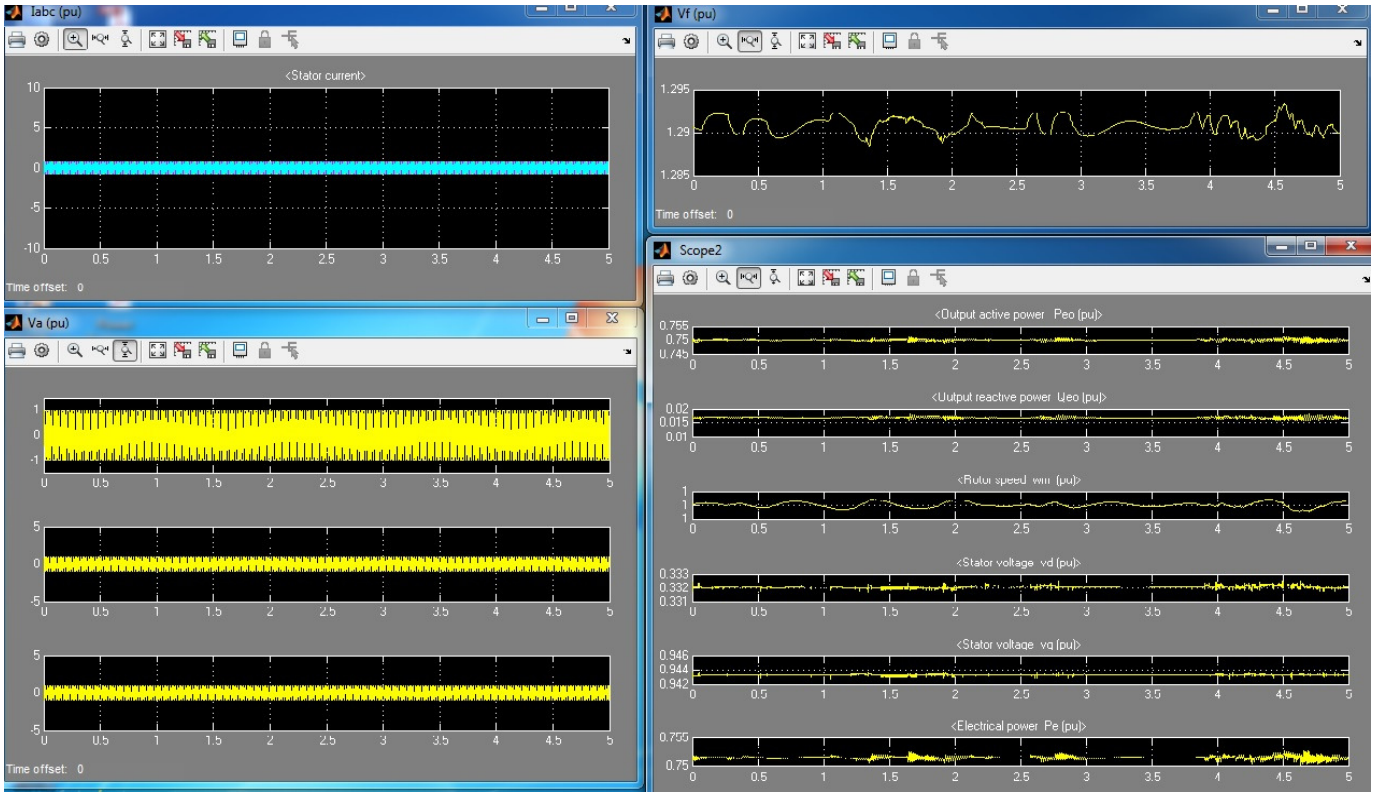


**Figure 6.1 characteristics without integrating wind turbine**

**6.2 Case II characteristics with integrating wind turbine for feeding 10 MW load:** Scope1 represents the characteristics of wind turbine which are represented in the figure 6.2. Iabc are the characteristics for the stator current. Scope2 represents the characteristics for the HTG. Vf are the characteristics for the excitation system. Va represents the phase voltage. Iabc, Va, Vf and scope2 characteristics are represented in the figure 6.3

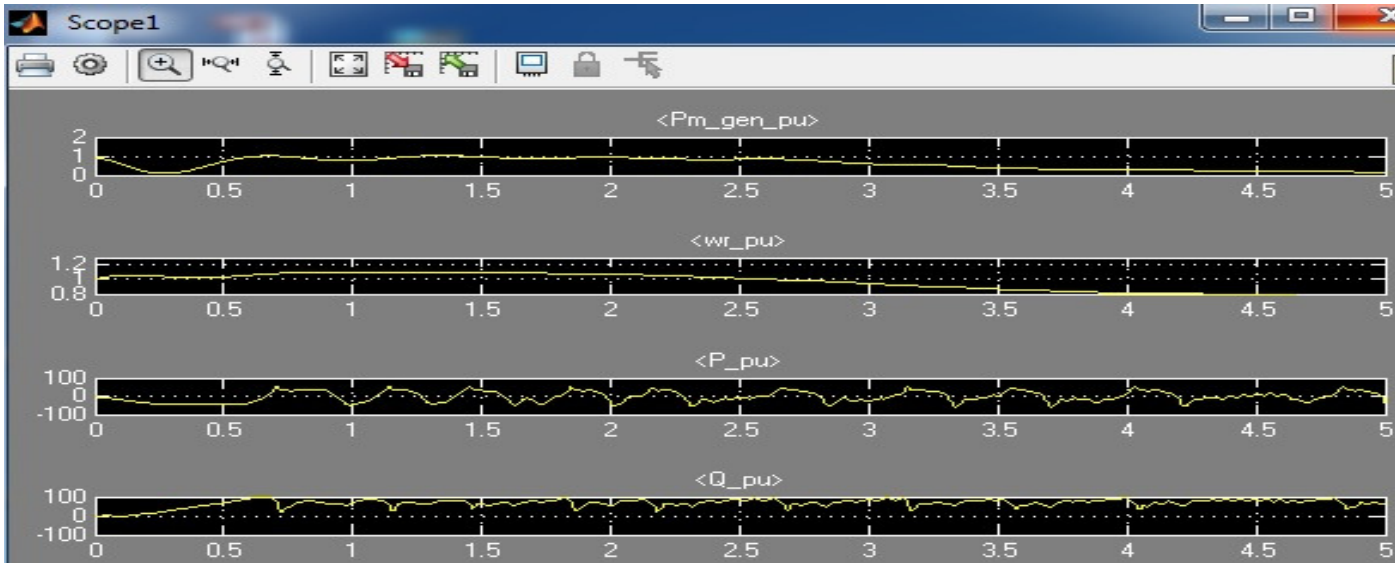


**Figure 6.2 Wind turbine characteristics**

***Discussion***

Incase II when the integration of the wind power system is done to fed the load of 10MW which is generally located far away from the hydroelectric power system than the stator current and the phase voltage characteristics which are shown in the figure 6.3 which comes out to be uniform and constant and in phase with respect to the stability of the system. In figure 6.3 the characteristics of the hydraulic turbine and governor are shown from which it was analyzed that the output active Peo and reactive power Qeo, stator voltage Vd and Vq, electrical power Pe are constant and uniform and are not varying simultaneously and are constant which results into a stable state. When we talk about the characteristics of the Peo and Qeo in figure 6.3 than from 0 to 0.5 seconds there were frequent oscillations but after 0.5 characteristics was almost constant. The rotor speed Wm in pu is almost constant from starting, as the burden on the rotor of the SM was reduced by the integration wind power with hydroelectric power system. This results into an improved and efficient transient stability of the system.

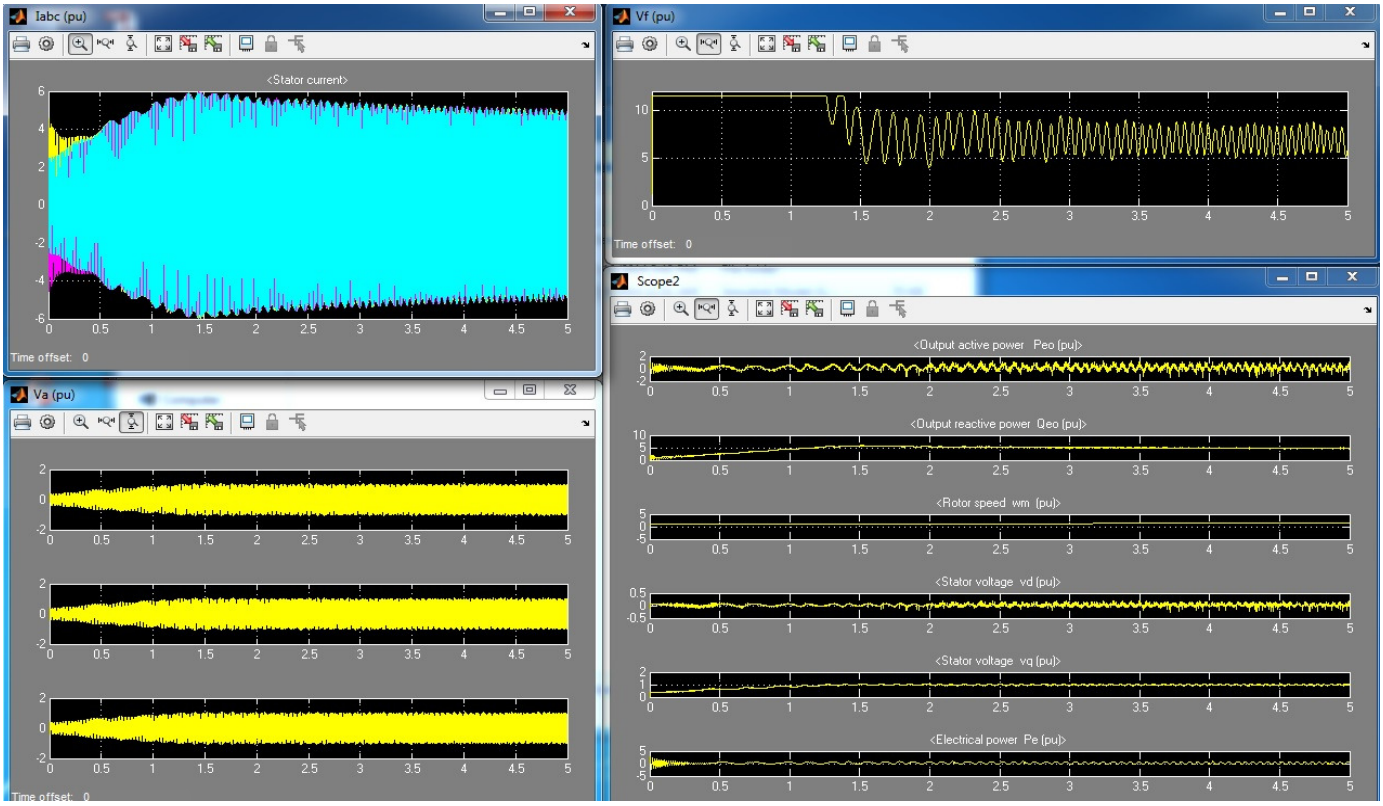


**Figure 6.3 Characteristics with integrating wind turbine**

## 7. CONCLUSION AND FUTURE SCOPES

### *7.1 Conclusion*

In this research work the analysis of transient stability of the small hydroelectric and wind power hybrid power system have been done in order to achieve an optimal operation of wind power integration in small hydro electric power plant. So that it should eliminate the transients and fluctuation and increase the desired electrical energy output to the consumers in the rural areas and weak and isolated parts of the grids. A model of small hydroelectric and wind power hybrid power system was developed and was simulated in the MATLAB/SIMULINK version 8.3 R2014a. By the characteristics it was found that integration of wind power plants with small hydroelectric power plants is suitable and successful in order to fulfill the supply of electrical power for a load away from the hydroelectric generation unit. The burden on the transients in the power system was reduced by integrating wind power with hydroelectric power resulting into a system with improved and efficient transient stability.

### *7.2 Future scopes*

This paper involves the investigation of the transient stability of the integrated wind power system with the hydroelectric power system. So in future there is need to investigate the frequency stability and voltage stability of integrated power systems. As investigation was done without taking in account some of power system parameters, so in future investigation on transient stability can be done considering whole parameter, if possible, further investing on the efficient generation and economic transmission. Investigation with

more than one hydroelectric or wind power system can be done in future. Effect of transients on integrating other power systems like thermal power system, solar panel, biogas plants etc has to be investigated in the power integration technique of hybrid power generation in future.

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