ANALYSIS OF SIMULATION MODEL OF MINI HYDRO POWER PLANT IN THE PERSPECTIVE OF BANGLADESH

Abdullah Al Mahfazur Rahman and Md. Rakibul Hasan

***Abstract*—**The grid-connected mini-hydropower plants have significant prospects in Bangladesh. It can provide financial and environmental benefits as it is a clean source of energy. But the behavior of this type of system under steady-state and faulty conditions of the grid needed to be realized for the design perspectives. This paper demonstrates a simulation model of a mini-hydropower plant that can be connected with the distribution system under steady-state and dynamic situations of the distribution grid. During the fault, the system starts to oscillate. But as the circuit breaker reacted to the fault, it makes the system back to stability. This type of analysis will be helpful to design the protection system for grid-connected mini-hydropower plants. The simulation is carried out in the MATLAB/Simulink platform. The behavior of the system can be observed by the waveforms of voltage, current, and rotor speed at the generator's terminal.

***Keywords*—**Small-scale hydropower, mini hydropower, mini grid, three-phase fault.

I. INTRODUCTION

THE electricity demand of Bangladesh is increasing rapidly with the overall development of this country. The production of electricity in Bangladesh is mostly depending upon conventional energy sources like oil, gas, and coal [1-3]. But the continuous use of natural gas for the production of electricity is ultimately creating pressure on the natural gas reserve. On the other hand, if we chose the coal-based power generation technique instead of gas then we need more coal to meet the power demand of this country. To facilitate the power demand the country requires to import petrol and diesel from other countries. The imported diesel could be used in agriculture and various vehicles. But most of the diesel is used to generate electricity to meet the electric power demand. Carbon dioxide emissions increased due to the huge use of fossil fuels like coal and diesel eventually leads to global warming [4-5]. If reduction of CO_2 is not possible huge areas of the earth will be submerged. Renewable energy-based sources play a small role in the overall power generation of this country. If a significant amount of alternative sources are not integrated with the grid, there will be more demand for natural gas in the future [4, 6]. So, it is important to generate electricity using renewable energy. The hydropower plant is considered one of the most efficient and cleanest sources of energy to produce carbon-free electricity [7]. The technology of the large-scale hydroelectric power plant is established in Bangladesh. But this technology requires a reservoir and a significant amount of land area. As a result, the overall installation cost is very high. Moreover, it harms the ecology of the rever system. The construction of dams and reservoirs threatens the nearby wild lives [8]. It hampers the cultivation process of that area. But there are some other topologies of hydroelectric power plants that can overcome the problems as mentioned in [9].

According to power handling capacity, the classification of hydroelectric power plants is given in TABLE I [9]. The installation procedure of Mini Hydro and Micro hydropower plants are similar. Unlike large hydropower plants, it can cause less impact on the environment. Because this type of system does not require building a dam and reservoir system. The flowing water transfers to the turbines through the penstock helps to rotate the turbine. A shaft connects the turbine with the rotor to produce electricity. The flowing water returns to the river after passing through the turbine blade. As a result, this water can be used for irrigation purposes and it can provide less ecological impact [10]. Usually, a Micro hydropower plant provided power for a small community or rural areas away from the grid. Sometimes Mini and Micro hydropower plants are connected to the public grid. This type of system has very little impact on the environment if we compare it with the fossil fuel-based power plant.

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In comparison with other small scales, renewable energy sources mini-hydropower plants are more reliable and can provide a continuous power supply to the consumer. It also poses low operation and maintenance costs in that context.

TABLE I
HYDROELECTRIC POWER PLANTS BASED ON POWER RATING

Sl	Type	Power rating
1	Large	More than 100 MW
2	Medium	10 to 100 MW
3	Small	1 to 10 MW
4	Mini	100 kW to 1 MW
5	Micro	5 to 100 kW
6	Pico	Less than 5 kW

The major challenge for this type of system is the integration with the power grid. Under these circumstances, the system has to deal with many technical challenges like the system behaviors under steady-state and dynamic situations of the grid. For the stable operation of the system, the behavior under major disturbances like three-phase faults is needed to be considered. It is required to design the protection of the system against any type of power system fault. For this reason, a simulation model of a mini-hydropower plant-based network is designed to meet the power demand of the distribution system. The electrical behavior of the system is observed and analyzed under a steady-state and faulty condition on the HT side of the network. The system behavior using a circuit breaker on the HT side of the transformer is also observed.

II. LITERATURE REVIEW

Hydropower power plant at any scale always provides clean energy and is considered one of the prominent form of renewable energy. Researches show that Bangladesh has a huge potential to generate electricity from small scale and mini-hydro power plant [3]. But to get the effective use of this type of project needs extensive technical research. Numerous research has been conducted on this issue. Integration of mini-hydropower plants with the grid and its requirements and challenges are explained in [10-11]. The modeling of a small hydropower plant with a battery storage system is explained in [12]. The model is simulated and tested under a transient stability condition to its stability under that type of situation. The use of mini-hydro and wind turbine-based hybrid systems with a supercapacitor as energy storage systems is explained in [13]. This type of system can give stability to the weak power grid. It can also contribute to high power penetration to the conventional grid. The small scale and mini-scale plants have to face many technical issues such as grid synchronizing, thermal limit, stability, frequency variation, and power quality that are explained in [14]. A renewable energy-based system can behave like a conventional source under steady-state operation. But it should have the capability to behave like a conventional energy source during power system major faults for a specific time. The system must have to comply with the low voltage ride-through capability as mentioned in the grid code of Bangladesh in [15]. Considering these technical issues the network is designed and simulated under certain conditions of the distribution grid.

III. CONSTRUCTION AND MODELING OF MINI HYDRO POWER PLANT

To convert the kinetic energy of water to electrical energy a proper structure is needed [16]. For that, a suitable site selection is very important to the construction and development of a mini-hydropower plant [17]. If the distance of the plant is far away from the community then the cost of transportation will increase which will ultimately increase the installation and maintenance cost of the site. For the construction of a mini-hydropower plant hilly area is most popular because of its good water head [18-21]. In other places, it is also possible to construct a mini-hydropower plant but the availability of river water or cannel is essential. Flowing water, store water, surge tank, valve, penstock, turbine, a generator are the main parameters of a mini-hydropower plant. A dam is a structure for accumulated water. If the distance between the power house and the customer is reduced then power loss of transmission line is less [8, 22].

The production of power from a hydroelectric power plant depends on the flow rate of water and the water head which is represented by equation (1) [11, 23].

$$P_h = \rho g Q H \quad (1)$$

,where P_h represents the hydraulic Power, ρ is the density of water, H in the water head, g is the gravity and Q is the discharge rate.

But the conversion of electric power from hydraulic power depends upon the effectiveness of the system, which can be represented by equation (2).

$$P_e = \eta P_h \quad (2)$$

,where P_e represents the electrical power and η represents the efficiency of the designed system.

IV. SIMULATION MODEL OF THE SYSTEM

The simulation model of the mini hydroelectric power plant is shown in Fig. 1. The specification of the system is given in Table II.

TABLE II
SPECIFICATION OF THE NEWTORK

Sl	Quantity	Power and Voltage
1	Synchronous Generator	180kVA, 400V,
2	Transformer	250kVA, 400V/11kV
3	Load-1	45kW, 400V
4	Load-2	50kW, 400V
5	Load-3	80kW,11kV
6	Mini grid	100MAV, 11kV

For the hydropower plant, a synchronous generator is considered with a capacity of 180 kVA and the rated voltage is 400 V. A three-phase transformer is installed to step up the voltage to 11 kV with a capacity of 250 kVA. Load-1 and 2 are connected on the LT side of the transformer with a capacity of 45 kW and 50 kW and Load-3 is connected on the HT side of the transformer with a capacity of 80 kW. 11 kV distribution grid is considered with a capacity of 100 MVA.

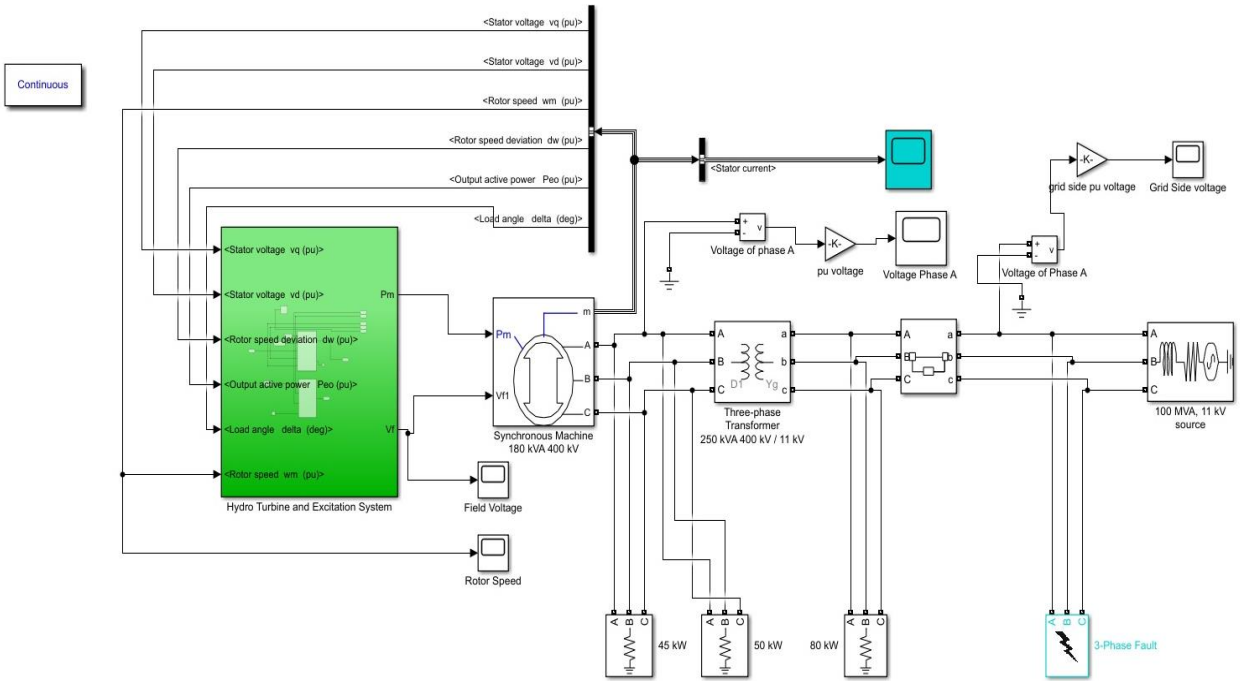

Fig. 1. Simulation model of the mini-hydropower plant with the associated network

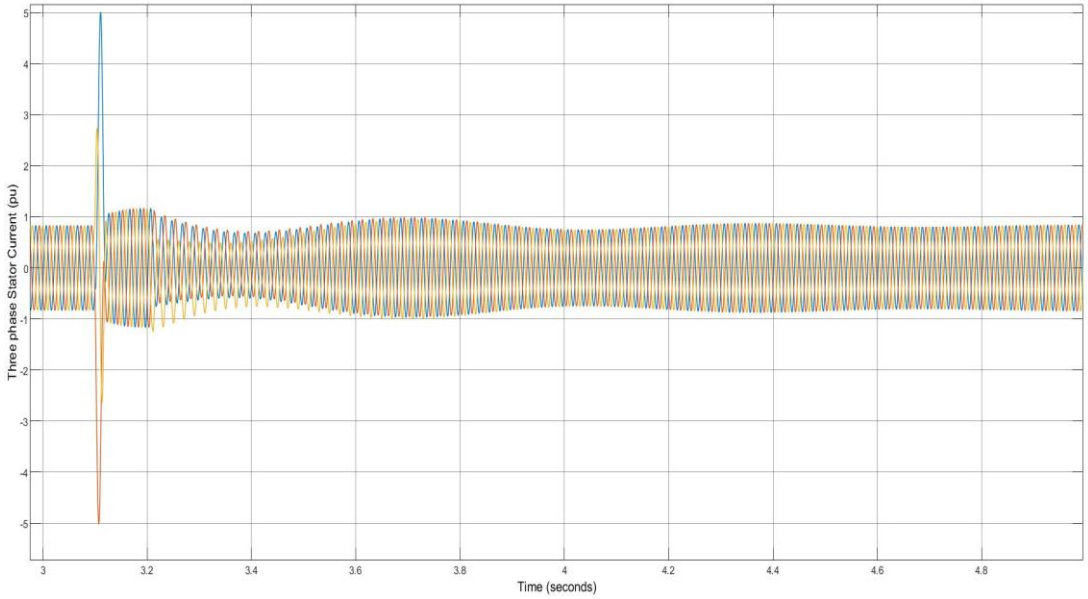

Fig. 2. Three phase stator current of the generator

Fig. 3. Phase voltage of the generator

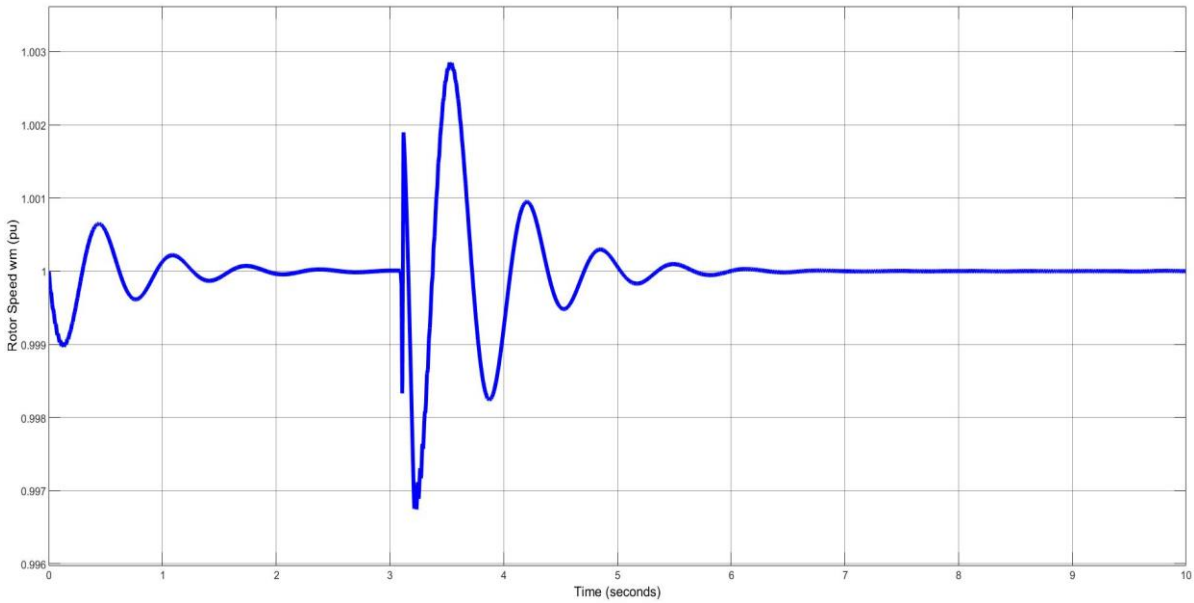

Fig. 4. Rotor speed the generator during the three phase fault

V. Result Analysis

A. *Observation on the stator current*

Under steady-state situation, the three-phase stator current is stable and maintained a value of 0.9pu which is shown in Fig 2. When a three-phase fault occurs at 3.1 sec the sub-transient current becomes very high. The amplitude of current at that tion was found 5 pu. But when the circuit breaker reacted at 3.11sec the stator current reduced and became stablized very quickly.

B. *Observation of the terminal voltage*

From Fig 3, it is found that the system voltage is maintained at 1pu before and after the fault. During the fault as the circuit breaker reacted very quickly, that's why the system voltage was restored instantly.

C. *Observation of the rotor angle*

From Fig 4, it is found the rotor speed is maintained 1pu before the fault. When the faults occurred in the system the speed controller of the system tried to restore

speed. But the rotor started to oscillate. As the fault is cleared very quickly the controller manages to make the speed again at 1 pu. If the fault would not be cleared very quickly it would hot be able to restore the speed and the system would become unstable.

VI. CONCLUSION

The modeling of a grid-connected mini-hydropower plant is presented in this paper. The simulation is performed in MATLAB/Simulink. The system is simulated under various steady-state and faulty conditions of the distribution grid. This analysis will be helpful to understand the impacts of power system faults on the grid-connected generators. Based on that, the protection scheme can be developed. To observe the dynamic behavior of the system a three-phase fault is created on the HT side of the transformer. The behavior of the system after installing a circuit breaker is also observed. The system behavior before and after clearing the fault was stable as was expected. This can be seen from the responses of current, voltage, and rotor speed waveforms. The scope of this paper was to observe the responses of the mini-hydro power plant under the steady-state and dynamic conditions of the grid. Before the fault, the rotor was rotating at its rated speed of 1 pu. But as the faults occur its starts to oscillate. It is would eventually make the system unstable if the protection system is not initiated within a short period. The stability of the system is restored under dynamic conditions of the grid with the coordination of the circuit breaker that is simulated by implementing a single circuit breaker at the HT side of the transformer. In the future, a complete protection system can be installed and analyzed for the system. The energy storage systems combining with mini-hydropower plants can increase the effectiveness of the system. So that type of system can also be added and analyzed with the existing model.

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