Integrating Micro Hydro Electric Power Schemes into Grid Systems: Review of Barriers, Procedures, Requirements and Problems

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Abstract

The grid integration of renewable energy has become more common in recent years. The reasons behind are the increase in world's electricity demand, power capacity improvement of local grids to meet up the escalating demand, increasing cost of fossil fuels, economic benefits of no fuel consumption by renewable energy sources, business opportunities, energy security, energy independence and more importantly the environmental concerns and global warming due to the excessive use of conventional energy sources. Like the grid integration of different forms of renewable energies, the integration of Micro Hydro Electric Power (MHEP) into grid systems is also imminent owing to its tremendous performance and potential benefits in terms of high efficiency, high capacity factors, low output power variations and greatly feasible with low investment costs when compared to other renewable technologies specifically wind, wave and solar power of the same size. This paper presents a review of the factors associated with the grid integration of MHEP schemes and discusses the key barriers, relevant procedures, major requirements and significant problems pertaining to their grid integration. Various strategies to overcome barriers and practicable solutions to mitigate and to compensate the problems encountered during grid integration are also described for consideration.

Keywords: *Renewable Energy (RE); Micro Hydro Electric Power (MHEP); Grid Integration, Distributed Generation (DG).*

1 Introduction

Micro hydroelectric power (MHEP) is a kind of hydro power scheme that can generate electricity up to 100 kW using water flow [1]. It is an excellent way of harnessing renewable energy (RE) from small streams and rivers. It appears as a clean, attractive and the highly expanded source of RE over the world that has certain benefits over its large scale hydro counterparts. These potential benefits are as follows [2-7]:

- Efficient energy resource.
- Reliable source of electricity.
- No reservoir required because of run-of-river structure: the water runs straight directly through hydro turbine and drop back into the river to utilize it for other purposes.
- Low ecological impacts on surroundings.
- Cost effectual energy solution: as no fuel cost, operation and maintenance expenditures are also reasonably low in comparison to the same size of other technologies of RE.
- Energy for developing and under developing countries: micro hydro has economical adaptability and versatility, and lengthy span of life.
- MHEP can be used to supply electricity to small rural and isolated communities.
- Minimum environmental impacts in comparison to the conventional power plants that utilize fossil fuels.
- Have low failure and malfunction rate.
- Have quick start-up and make fast adjustments in the output power.
- Can be integrated with the electric grid system: if the produced power is surplus, utility companies can purchase the generated electricity and integrate it into the local grids.
- There can also be a chance of enhancement of micro hydro power level with intake from the integrated connected grid.

The MHEP schemes are generally used to feed power to remote isolated residences or communities where electricity grid is not available, and/or the grid system extension is not economically practicable due to large investment required for transmission/distribution network [8]. However, in recent years, their integration back into the local grid system when the produced electric power is in excess is also evident [3]. It is mainly due to their confirmed advantages in terms of good performance such as high efficiency (70-90%), high capacity factors (> 50%), approximately constant output power and being highly feasible with low investment costs when compared to the same size of other renewable technologies specifically wind, wave and solar [2, 9, 10, 11, 12]. Moreover, the payback period for grid integrated systems is reasonable, often 5-8 years or less [11-13]. Therefore, where the potential sites are available near to the local grids, MHEP systems can be functioned in integration with the main grid systems. The major motives behind are to attain financial advantage of no fuel consumption by water turbines, power capacity enhancement of local grids to catch up the rising load demand and to keep the electric supply uninterrupted in the system [14].

Usually, all the renewable energy technologies including MHEP are considered as intermittent sources of power, therefore their integration with the grid system infrastructure is a difficult task [15]; which leads to various complexities and risks that range from power production to load management and from reliability to cost efficiency of power supply. Though, their grid integration facilitates to increase the plant load factor by generating additional revenue which ensures sustainability of the projects. In addition, it decreases the dependability of the distribution network on a single point of supply; thus helping the grid integration of distributed generation (DG) to reduce transmission/distribution losses [16]. But, there are several factors exist pertaining to the grid integration of MHEP based renewable energy systems [10, 17, 18, 19, 20] that need to be considered and addressed appropriately in order to gain the full advantages of integrating MHEP schemes into grid systems. So, this paper reviews and presents all these factors include key barriers, relevant procedures, major requirements and significant problems for the grid integration of MHEP schemes followed by various solutions.

The paper is organized as: section 1.1 presents the general layout of MHEP scheme. Section 1.2 and 1.3 give the key barrier including overcome strategies and relevant procedures for grid integration of MHEP schemes respectively. While, the major grid integration requirements and significant problems along with the solutions regarding to the grid integration of MHEP systems are discussed in section 1.4 and 1.5 respectively. Conclusions followed by the acknowledgment and references are presented in section 1.6.

1.1 General Layout of MHEP Scheme

Micro hydro power is based on the principle that falling and flowing water has a certain amount of potential and kinetic energy [21]. By means of a turbine or water wheel, this energy in falling and flowing water is converted into useful mechanical energy. Then, through an electric generator, the produced mechanical energy is converted into electrical energy.

Fig. 1 illustrates the general layout of a typical MHEP scheme. The water is diverted through an intake weir from the river. The diverted water then goes towards settling basin where it is sufficiently slowed down to settle out the suspended particles. Then water from settling basin is brought to a forebay tank through an open channel or canal, which makes sure and maintains a constant head of water before entering to a penstock. In the tank, debris is filtered and water is conveyed to turbine through penstock (a pressure pipe that leads water directly towards the turbine). The power conversion process takes place inside the power house, the hydro energy stored in water is converted into mechanical energy by a water turbine and this converted energy from turbine is transferred to generator that converts it into electricity. Lastly, after energy extracting from water flow, the water from turbine again releases back into river through a tailrace.

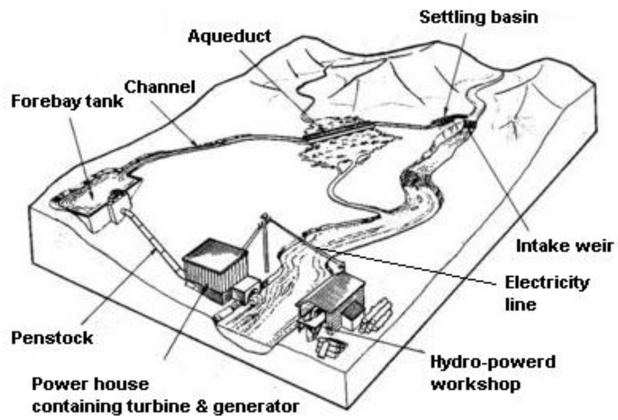

Figure 1 General site layout and components of a typical MHEP scheme (source [22])

1.2 Key Barriers and Overcome Strategies

Due to the growing energy demand and environmental concerns, the grid integration of MHEP based DG has gained a great popularity in the electricity market throughout the world. However, in spite of this, certain key barriers still exist that need to be overcome. These key barriers are listed as follows [23]:

- Lack of marketing.
- Utilities framework and culture.
- Strength of integrated grid.
- Transmission/distribution access.
- Capital expenses vs variable energy costs.
- Limited role of private sector.
- Lack of expertise and capability.

Many studies are found in literature on grid integration of RE technologies, in which few have presented some policies to promote RE integration with local grid systems and strategies to overcome the obstacles arrive in the way of grid integration of DG. These strategies are given as under [23]:

- Train RE engineers, designers and operators.
- Promote market development.
- Support utilities RE procurement.

- Encourage private investors.
- Provide long term contracts.
- Facilitate and assist access to electricity grid.
- Value RE attributes.

1.3 Relevant Procedures

Codes, standards, and utility policies and procedures regarding grid integration of RE systems differ amongst regions and countries. However, in various countries, particularly in the developing world, these norms are not yet to be well defined and clear. And in countries where these things do not exist, grid integration is determined and resolve on a case-by-case basis. The majority of the public sector and/or private utility companies in such countries are unaware and unfamiliar with administrative procedures and technical standards for making grid integration. On the other hand, many countries exist in the industrialized world that offer simplified relevant procedures for RE based small and mid size DGs integration with grid systems; these are discussed as below [24].

1.3.1 Grid Integration Application

The first step of the process is to apply for grid integration interconnection. It should be transparent, clear and straightforward. Moreover, to ensure a reliable, safe, secure and perfectly metered utility interconnection, the provided information should be sufficient.

1.3.2 Approval of Utility

A utility should set appropriate criteria to approve, deny, or condition interconnection of a DG. The process of approval should be critically based on a series of questions and screens who decide which procedural pathway is followed by small power producer (SSP) to integrate their system.

1.3.3 Commissioning, Testing, and Follow-up

Once the permission is granted to integrate the DG with grid system. Regulatory authority and/or utility normally perform commissioning and testing of the project construction. In addition, SPPs are mandatory to submit periodic reports on their interconnected system, and the utility company reserving the right to execute any inspection of the system.

1.3.4 Implementation Responsibility: SPP or Utility?

The more common and conventional approach to utility grid interconnection of DG for integration is that SPP to work for installation of equipment on its side of the PCC (point of common coupling) and the utility to work on its side of the PCC with having the right to examine equipment and their installation on the SPP side of the system also.

1.3.5 Metering

The metering as a rule is installed at or near the PCC. The modern digital meters are better than conventional analog meters as they measure in much wider range such as current, voltage, real and reactive power, maximum demand, and time of use while analog meters measure only net collective energy. Now, digital meters are incorporated with modern communication technologies to send data wirelessly to SPP and/or utility, these meters come into the category of smart meters.

1.3.6 Integration Interconnection Cost

The costs linked with making a grid integration of DG consist of equipment costs, labor costs associated with intertie equipment installation, commissioning and inspection costs, utility administrative costs, and liability insurance particular to the grid integration. Normally, cost of interconnection depends upon type of DG and system size and it varies country to country.

1.4 Major Requirements

The grid integration of MHEP schemes technically demands and prefers synchronous AC interconnection of all interconnected systems [25]. At a common level, the first main requirement for both grid and interconnected DG is that they should share the common frequency either at 60 Hz or at 50 Hz [25]. Then, they must remain in synchronism by regulating frequency. The second major requirement is that they should be interconnected at a same voltage level [25]. However, along with the aforesaid requirements, some other major and common requirements for the grid integration of MHEP schemes should also be fulfilled for the safe and healthy operation of MHEP schemes in grid connected mode. These requirements are as follows [25-28];

- Overall design and structure of system.
- Safety of system and consumers.
- Safety of plant operating in parallel with grid.
- Protection of plant and system.
- Control and monitoring of system.
- Metering.
- High quality of power.
- Communication and data exchange.

Normally, MHEP schemes are installed either with induction generator or with synchronous generator. Each of these generators has certain features and characteristics that necessitate serious consideration when integrating them to the local grid system [24].

1.4.1 Synchronous Generator Requirements

Usually, synchronous generators require complex protection. They must be synchronized before being connected to grid in frequency and phase [28].

1.4.2 Induction Generator Requirements

While, induction generators are not synchronized before integration, as they need supply of reactive power from capacitor banks or grid to generate electricity. To limit the inrush currents, they are usually connected through a soft starter [28].

1.4.3 Human Safety Considerations and Requirements

This is also very important requirement that should be considered critically for human safety. For this purpose, install lockable switches at easily accessible positions [23]. On need, manually isolate renewable energy based DGs from grid. And also update circuit diagram regularly and display at appropriate locations [23]. Set up a direct communication between SSP and utility at any critical disturbance event.

1.5 Significant Problems and their Solutions

The renewable DGs are relatively small as compared to other generations and/or power sources of conventional nature on the grid. Their integration with the existing power system grid infrastructure can cause the instability of interconnected grid due to their erratic and intermittent power production nature. So therefore, to integrate them into the power grid system is a challenging task. Likewise, MHEP based DG systems are also intermittent nature, therefore their integration with grid creates many problems that must need to be addressed to gain the full RE resource potential. Hence, the list of problems encountered during the grid integration of MHEP schemes is as follows [23, 24, 25, 28, 29, 30]:

- Frequency fluctuations and regulation.
- Voltage rise and reverse power flow.
- Voltage imbalance.
- Voltage fluctuations and regulation.
- Output power fluctuations and regulation.
- Power factor (PF) correction.
- Harmonics distortion.
- Unintentional and safe intentional islanding.
- Control of faults in grid connected mode.
- Battery storage problems.
- Protection coordination.
- Loss of Synchronization.

Technically, the all aforementioned problems are very important for a power system. This is because the system's stability and security is strongly dependent on them. So, they must be address vigilantly and carefully. However, alongside these, some other problems are also need to be tackled. Such as, institutional cooperation, lack of trained man power, RE resource dispatchability and harmonization of technical standards among stakeholders.

1.5.1 Solutions

The growing strength of renewable energy resources and DGs necessitates innovative tactics and schemes for grid integration, operation, control and grid management so as to maintain and enhance the reliability and quality of power supply. Thus, keeping in view of the abovementioned problems for grid integration of MHEP systems, some potential solutions proposed in different studies are as follow [15, 23, 28, 31, 32, 33].

- Power electronics technology should be used for complex control of grid and integrated RE systems.
- Harmonic compensators should be used to reduce harmonic contents in power supply.
- Electromagnetic interference (EMI) should be minimized so that it cannot affect the operation of protection.
- Power conditioning system should be provided to control THD (Total Harmonic Distortion) and PF.
- Fast responding frequency and voltage regulator should be used.
- Batteries and auxiliaries should be sufficient capacity to ensure the operation of all protection during loss of supply.
- Proper monitoring and information exchange is extremely essential for better coordination.
- Automatic synchronization should be preferred for grid interconnection over manual methods.
- Protection should also be provided to avoid unsynchronized connection.
- System protection should also be provided against transient abnormalities at grid.
- Protection equipment must meet the standard requirements and there should be no compromise on at least minimum protection.
- Renewable energy technologies including MHEP should be excluded from the competition by giving them priority to dispatch.

1.6 Conclusions

This paper presents the review of different grid integration factors of micro hydro electric power schemes. The work describes the key barriers and strategies to overcome these hurdles in the path of grid integration. Alongside, the paper gives simplified procedures regarding the grid integration of MHEP based small and mid size DGs, and also presents the major grid integration interconnection requirements for AC synchronous interconnection. The significant problems encountered during the grid integration of MHEP systems are also presented in this review paper. Finally, the review also suggests and recommends a number of viable and achievable solutions to avoid and compensate the problems of voltage, frequency, and power variations and quality through appropriate control, synchronization and protection when integrating MHEP sources into the main or local grid systems.

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