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Design aspects and probabilistic approach for generation reliability evaluation of MWW based micro-hydro power plant ☆

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ABSTRACT

This paper presents the design aspects and probabilistic approach for the generation reliability evaluation of an alternative resource: municipal waste water (MWW) based micro-hydro power plant (MHPP). Annual and daily flow duration curves have been obtained for design, installation, development, scientific analysis and reliability evaluation of the MHPP. The hydro-potential of the waste water flowing through sewage system of Brocha sewage plant of the Banaras Hindu University campus is determined to produce annual flow duration and daily flow duration curves by ordering the recorded water flows from maximum to minimum values. Design pressure, roughness of the pipe's interior surface, method of joining, weight, ease of installation, accessibility to the sewage system, design life, maintenance, weather conditions, availability of material, related cost and likelihood of structural damage have been considered for the design of a particular penstock for reliable operation of the developed MHPP. MWW and self-excited induction generator (SEIG) based MHPP is developed and practically implemented to provide reliable electric power to charge the battery bank. Generation reliability evaluation of the developed MHPP using the Gaussian distribution approach, safety factor concept, peak load consideration and Simpson 1/3rd rule has been presented in this paper.

Contents

Abbreviations: BHU, Banaras Hindu university; MWW, Municipal waste water; SWW, Sewage waste water; BSP, Brocha sewage Plant; BSS, Brocha sewage station; MHPP, Micro-hydro power plant; MHPS, Micro-hydro power system; SHPP, Small hydro power plant; SHPG, Small hydro power generation; FDC, Flow duration curve; AFDC, Annual flow duration curve; AAFDC, Average annual flow duration curve; DFDC, Daily flow duration curve; ADFDC, Average daily flow duration curve; MFDC, Monthly flow duration curve; SHPGS, Small hydro power generation system; MHPGS, Micro-hydro power generation system; SEIG, Self-excited induction generator; PMG, Permanent magnet generator; HDPE, High density poly ethylene; uPVC, un-plasticized polyvinyl chloride; WWF, Waste water flow; MTTF, Mean time to failure; MTBF, Mean time between failures; MTTR, Mean time to repair; GDA, Gaussian distribution approach; PLC, Peak load considerations; SFC, Safety factor concept; LDC, Load duration curve; SLDC, Stepped load duration curve; LOLP, Loss of load probability; SF, Safety Factor; LPS, Litters per Second; MHT, Micro-hydro turbine; MHP, Micro-hydro power; MHPG, Micro-hydro power generation; SPS, Sewage power station; IST, Indian standard time; DPLVC, Daily peak load variation curve

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1. Introduction

Micro-hydro power generation system (MHPGS) is one of the popular renewable energy sources in the developing countries. MHPGS has obtained increasing interests in the 21st century due to their ecological irreproachability and acceptable prices for generating electrical power without producing harmful pollution and green house gases. MHPGS based on municipal waste water (MWW) is considered as an environment friendly renewable energy source since this can be sized and designed to limit the interference with river flow and canal flow. Most of the MHPGS's operate in isolated mode for rural electrification of remote villages where the population is very small and extension of the distributed grid system is not geographically and financially feasible due to the high cost investment in a power transmission system. Small hydroelectric power generation systems (SHPGS's) are relatively small power sources that are appropriate in many cases for individual users or groups of users who are independent of the electricity supply grid. Although this technology is not new, its wide application to small waterfalls and other potential sites like MWW based system are new [1]. SHPGS's are the application of hydroelectric power on a commercial scale serving a small community and are classified by power and size of waterfall. Small hydro-power plants (SHPP) can be divided into mini-hydro (less than 1000 kW capacity), and micro-hydro power system (MHPS) which has less than 100 kW capacity. Hydroelectric power is the technology of generating electric power from the movement of water through rivers, streams, and tides. Water is fed via a channel to a turbine where it strikes the turbine blades and causes the shaft to rotate. To generate electricity the rotating shaft is connected to a generator which converts the motion of the shaft into electrical energy [2].

Generally, in an autonomous MHPS, the small hydro-power generators (SHPG's) are the main constituents of the system and are designed to operate in parallel with the local power grids. The main reasons are to obtain economic benefit of no fuel consumption by micro-hydro turbines (MHT), enhancement of power capacity to meet the increasing demand, to maintain the continuity of supply in the system, etc. Small/micro-hydro is highly fluctuating in nature and will affect the quality of supply considerably and may even damage the system in the absence of proper control mechanism. Main parameters to be controlled are the system frequency and voltage, which determine the stability and quality of the supply. In a MHPGS, frequency deviations are mainly due to real power mismatch between generation and demand. Reactive power balance in the hybrid system can be obtained by making use of a variable reactive power device e.g. static VAR compensator [3]. Comparisons of various penstock materials have been presented considering friction, weight, cost, corrosion, joining and pressure for reliable operation of the MHPP. Hybrid power systems are the most attractive option for the electrification of the remote locations. These include high cost because of the system complexity, site specific design requirements and the lack of available control system flexibility. Many countries have targets and aspirations for growth in renewable energy. If a new alternative generation technology is introduced that makes a relatively low contribution to the reliability of meeting peak demand then additional capacity may be needed to provide system margin and cost is improved on the rest of the system. Quantification of the system costs of additional renewable in 2020 has been presented in [4].

MHPP using sewage waste water (SWW) neither requires a large dam nor is land flooded. Only waste water from different parts of the city is collected to generate power which has minimum environmental impact. After proper chemical treatment, water is provided to farmers for irrigation purpose. MHPGS using MWW of sewage plant can offer a stable, inflation proof, reliable, economical and renewable source of electricity. This alternative technology has been appropriately designed, developed and practically implemented at the Brocha sewage plant (BSP) of the Banaras Hindu University (BHU) campus. Reuse of the MWW can be a stable, inflation proof, economical, reliable and renewable energy source of electricity in the power scenario of the 21st century [5].

This paper is organized as follows: Section 1 presents an overview on MHPGS based on MWW. The selection criteria and brief descriptions on basic components of designed and developed MHPGS at BHU campus is described in Section 2. Selection criteria of penstock pipe materials, water turbines and various generators for different head are explained in this section. Annual, monthly and daily flow duration curves (AFDC, MFDC and DFDC) have been obtained for design and development of the MHPP based on MWW by recording water flow rates in Section 3. Generation reliability of constructed MHPP has been evaluated using the Gaussian distribution approach