Analysis of local grid stability by Hydrokinetic Turbines around a Hydropower Plant in India

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Abstract

Indian proverb, "the utmost darkness is under the oil lamp", is indeed true in relation to present scenario in places under local distribution grids in India, situated around the Hydropower plants. These conventional hydropower plants use hydrostatic energy for power generation with a conversion efficiency of 85-95%, whereas the energy possessed by available body of moving water around the plant, known as "Hydrokinetic energy", is difficult to extract due to low flow rates.

This poster, prepared in collaboration with Smart Hydro Power GmbH, Germany presents the impact of " Combined Cycle Hydroelectric Power System"- a combination of hydropower plant and hydrokinetic turbines, to provide additional power to the local grid situated around an existing hydropower plant. It intends to show that, for water rich areas, hydrokinetic turbines are an inexpensive option and offer a viable solution for securing reliable power and stabilizing the local grid situated around a hydropower plant.

Hydrokinetic Turbine

Hydrokinetic Turbine and principle of its operation

Hydrokinetic turbine (Figure 1) produces power from the speed of water and is therefore also known as "**zero head**" or "**in-stream**" turbine. It can operate in base load fashion and delivers energy as long as water keeps flowing. In this way it is a continuous renewable power source.

Output power of a hydrokinetic turbine is given by:

$$P = 0.5\, \rho\, A\, v^3\, C_p\, (\lambda, \beta)$$

Where **P**=Power (W), **ρ**= density of water (kg/m^3), **A**= blade swept area (m^2), **v**= velocity of water (m/s), C_p = power coefficient of the turbine which is determined by the value of **λ** (tip speed ratio) which is defined as the ratio between the tangential speed of the tip of the blade and the actual velocity of wind and **β** (fixed pitch angle). So the maximum power extraction (Figure 2) of 59% occurs at different speeds, which is also called **Betz limit**.

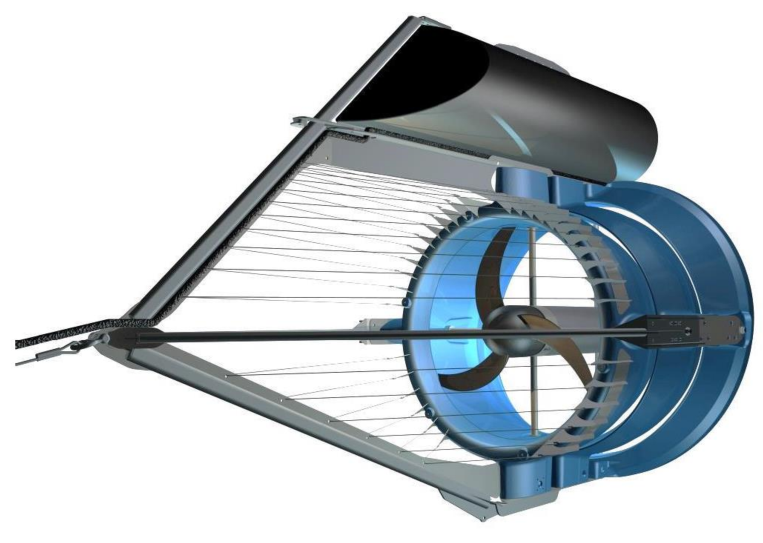


Figure 1. 5 kW SMART Monofloat Kinetic Micro Hydro System

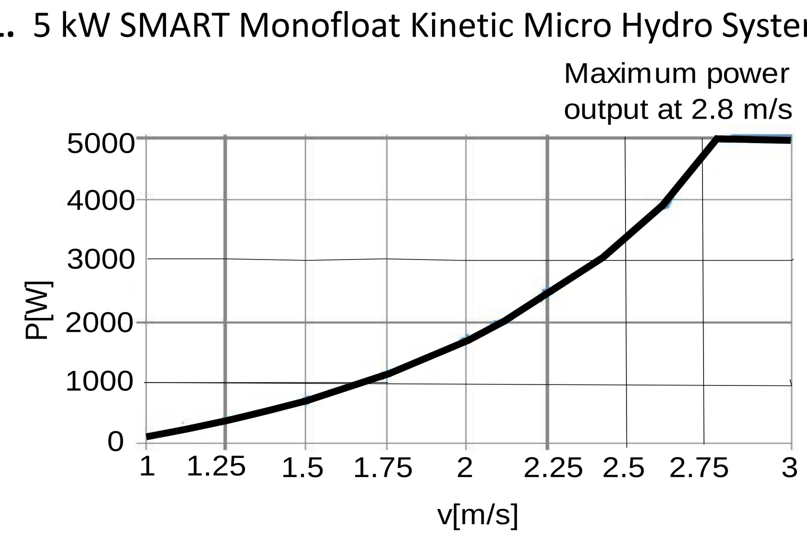


Figure 2. Operating curve of SMART Monofloat Kinetic Micro Hydro Generator

Background of the Problem

Grid in and around hydropower plants in India

Hydropower plants in India are normally located at remote areas, away from load centers. They mainly feed power at high voltage (400 kV, 220 kV, or 132 kV) to the national grid or intra-state grid depending on the owner of the power plant, after using around 1% of the power generated for auxiliary consumption and transformation losses.

Local grid around the hydropower plant is usually characterized as dispersed load with low demand and in turn causes high capital cost for grid electrification. In order to cut down the cost, power is supplied through a radial grid, which is drawn over from a long distance, with no provision of redundant line for rerouting power in the event of failure of main line. The radial grid thus suffers from high transmission and distribution losses, coupled with frequent supply interruptions and low voltage problems- many times in spite of the fact that generating station is located in the close vicinity. This is where hydrokinetic turbines offer a viable solution for securing reliable power and stabilizing the grid.

Methodology

A radial local distribution grid around the hydropower plant is modeled and simulated using the software Power World Simulator and consists of four distinct subsystems:

1. 33/11 kV distribution substation.
2. 11 kV transmission line of length 10 km with resistance of 0.9077 Ω/km and inductance 10^{-6} H
3. Three phase 200 kVA,11kV/440V distribution transformer with series resistance of 0.619 p.u. and series reactance of 0.000010 p.u.
4. Three sections of 440 V distribution line, each with 30 kW load, with a power factor of 0.85.

The losses for the existing system and then by integrating 5 kW SMART Monofloat Kinetic Micro Hydro Systems operating at unity power factor to the existing radial grid are observed. Integration is quantified using two different aspects (Figure 4):

1. **Penetration level:** Number of turbines that can be integrated are calculated as the total integrated capacity of hydrokinetic turbines (P_{hk}) over the peak local demand (**P_{load}= 90 kW**) and three scenarios are defined: 33% , 66% and 100 % penetration scenario.
2. **Injection points:** Places in the radial grid where the additional generation can be integrated i.e. Single Point Injection, Mid Point Injection and Load Point Injection.

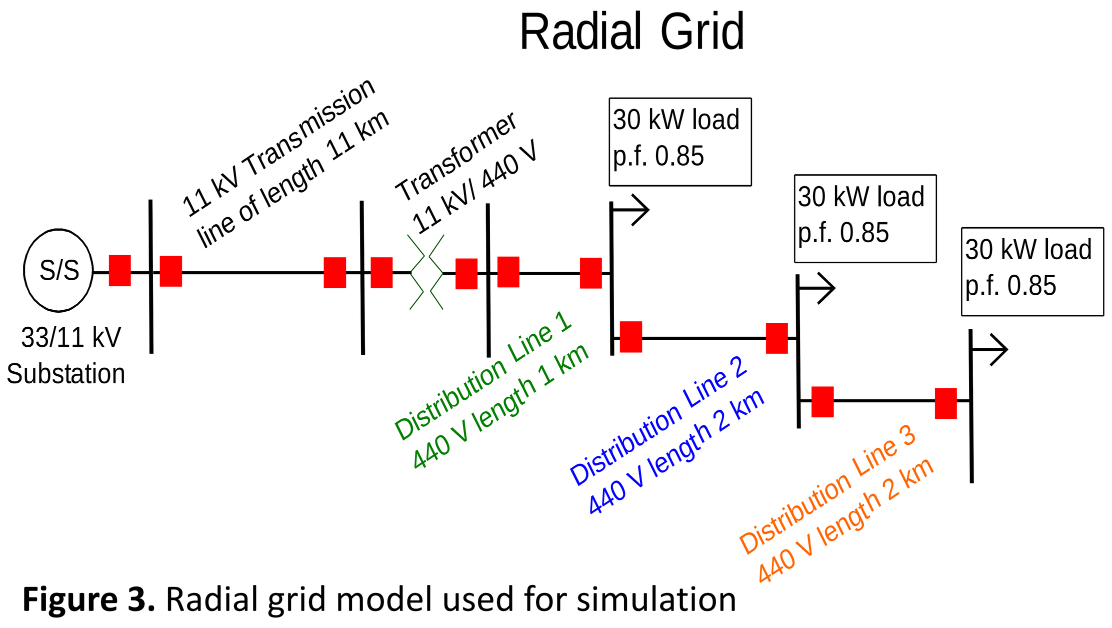


Figure 3. Radial grid model used for simulation

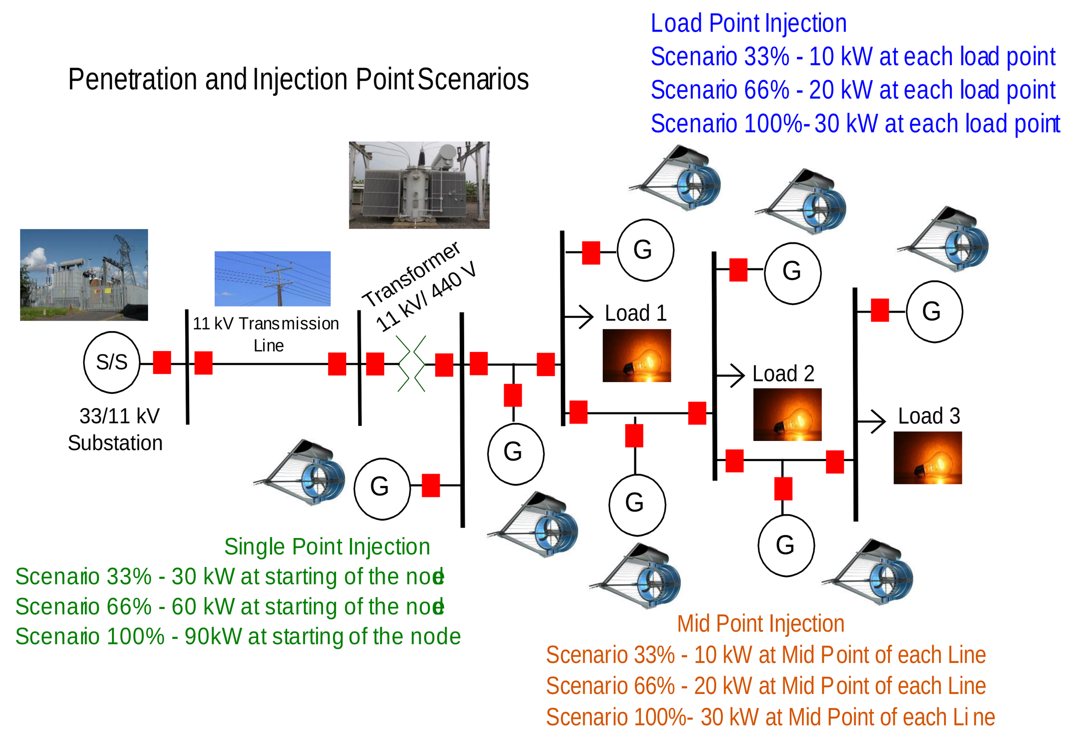


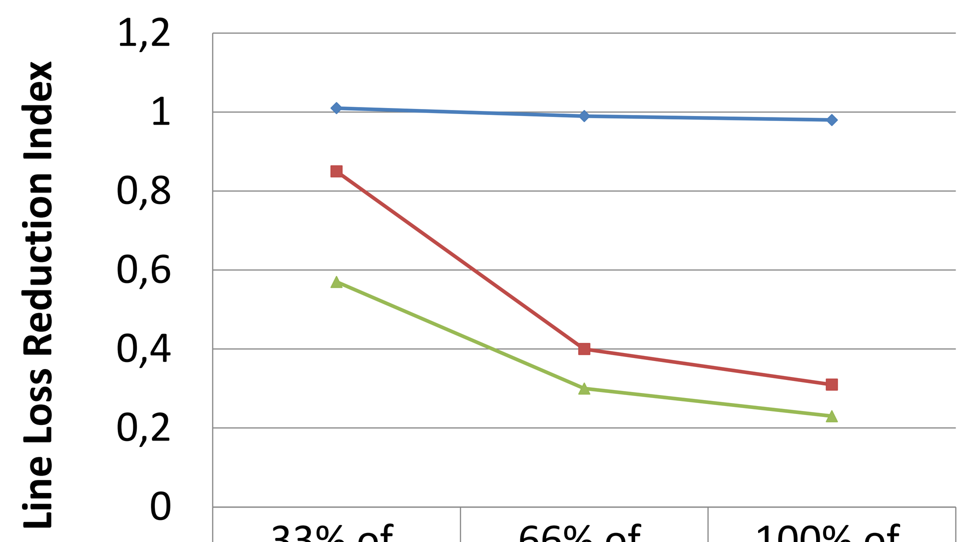
Figure 4. Different Injection Points were additional generation can be integrated

Results

In order to quantify the impact of integrating hydrokinetic turbines (Chart 1) in the radial grid the term **Line Loss Reduction Index (LLRI)** has been defined, which is given by:

LLRI= LLwhk /LLwohk

Where **LLwhk** are the total line losses in the grid with hydrokinetic turbines and **LLwohk(=14.05 kW)** are the total line losses without.



	33% of peak local demand	66% of peak local demand	100% of peak local demand
Single Point Injection	1,01	0,99	0,98
Mid Point Injection	0,85	0,4	0,31
Load Point Injection	0,57	0,3	0,23

Chart 1. Impact of integrating hydrokinetic turbines

Discussion

The Line Loss Reduction Index (LLRI) shows that the technical losses decrease and the stability of the radial grid increases as hydrokinetic turbines are dispersed and are operated at peak load demand closer to the load. However, integrating hydrokinetic turbines equal to the peak load demand can lead to increase in technical losses and instability of the radial grid, when there is decrease in load demand.

Future Work

To design and control an auxiliary load such as water purifiers, water pumps, ice makers and water heaters, which can consume power, when it is excess in the local grid. The designed system will then allow to operate hydrokinetic turbines at peak load demand and will manage power flow between radial grid, auxiliary load and battery storage.

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