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Control of PV-Hydro Micro-Grid with Energy Storage System Controlled Through Bidirectional Converter

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Abstract— Traditional ELC for MHP system is designed in such a way that it could be used to maintain the speed of the MHP plant in an isolated micro-grid system where the excess of the electrical energy is dumped into the dummy load during lightly loaded condition. But this system seems ineffective and carries the limitations such as waste of the energy during the lightly loaded period, unstable system during the peak load period, system instability during connected with the grid system and so on. Thus, this report aims to suggest a measure for the limitations through the project," Control of PV-Hydro micro-grid with energy storage system controlled through bidirectional converter". All the components are designed, calibrated and synchronized with each other using the MATLAB Simulation Software. Initially, PV plant and MHP plant is designed with capacity of 50KW and 100KW respectively. Inside the PV plant inverter and inverter controller is designed in such a way that is always produces the 400V across the output terminal despite the variation in Temperature and the Irradiation. There by implementing the MPPT (Perturbation and observation (P&O)) algorithm we were able to design the PV System Next, is we have designed the MHP plant that produces the 100KW power at 400V whose excitation and rotor speed is maintained throughout the operation at any load condition. The bidirectional converter with the battery backup system is responsible for maintaining the rotor stability at any load condition i.e. either lightly loaded or heavily loaded condition. The main aim of this project is designing a system where the system will store the excess of the energy in the battery during the lightly loaded condition while maintaining the rotor stability whereas the system will then again act as a source during the peak period when the PV-Hydro system is unable to meet the load demand.

Keywords— ELC, Bidirectional converter, MPPT, Micro-grid, Hysteresis band current controller.

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Introduction

The fact that power demand is rising daily but there aren't enough resources to meet it using conventional sources. This is one of the main issues facing the power system. The need to use conventional energy systems in addition to renewable ones in order to meet demand for energy has grown. The main energy sources that are being used in this regard are renewables like solar energy. Fossil fuel consumption has resulted in a decrease in the fossil fuel deposit, severe environmental effects, the depletion of the biosphere, and a cumulative increase in global warming. Because solar energy is so widely available, it may be harvested and used effectively. Depending on whether a neighboring grid is available, solar energy can be produced either independently or in conjunction with it. As a result, it may be utilized to supply electricity to remote locations with very little access to grid power. Utilizing solar energy also has the benefit of being portable, allowing for use whenever and wherever needed. The current energy issue must be resolved by creating an efficient and effective method for extracting energy from incoming solar radiation. The optimum power can be extracted by using the MPPT algorithm to control the boost converter in such a way that the power is optimum at any temperature and radiation making voltage constant. And for the PV system to convert the power from DC to AC an inverter must be designed controlled through the inverter controller which would in turn controls the power conversion by generating the appropriate PWM signal which would be fed to the controller and obtain the required AC output from the system. Hydro-electric plants of capacities ranging from 10 kw to 100 kw has been classified as Micro Hydro Power Plants (MHP) in Nepal. Most of the MHP plants are isolated plant supplying power to the rural area (where there is no National grid supply) where population is very small. Electrification of such rural areas by extension off national grid is not economically feasible due to the high cost of transmission line and large power loss in transmission line. MHP plant is one of the economical solutions to electrify such rural areas. A micro-grid scheme is a group of interconnected loads and distributed energy resources that acts as a single controllable entity with respect to the grid. It can connect and disconnect from the grid to operate in grid-connected or island mode. The dependability and resilience of customers to grid disruptions can be enhanced via micro-grids. At the moment, energy management techniques are becoming more and more crucial in 1 controlling micro-grid power quality. Controlling energy flows to meet different operational goals, such cost reduction, guaranteed supply, or security, is one of the issues. Changing the energy flow to and from the main grid, the distribution of energy resources, and the controllability of loads are a few ways to do this.

This kind of approach, which is today referred to as a home electricity management system (HEMS), is mostly used in the residential sector to encourage the integration of renewable energy sources and safeguard the electrical distribution system against possible blackouts. By using the ELC to control the power flow in the grid system we can make the system effective and resilient against the various transients and faults on the generating sides. And traditional approach of the ELC system is basically the wasting of the usable energy through the ballast load in the form of the heat but at the peak load the loads have to be optimized in order to maintain the supply to demand constant [1]. Thus, it can state that using the ballast load is only solving the problem partially but in order to make the system more resilient, battery back-up system controlled through the bidirectional controller as an ELC can be added, which in turn will maintain the grid stability in the load as well as source side. During lightly loaded period the battery will be acting as a load and is in charging mode where-as during the peak load period the battery will be acting as a source and will be supplying the required power to the grid while maintaining the rotor speed and constant voltages. This approach involves the use of DC-AC/AC DC bidirectional converter in such a way that it senses the variation of the load and frequency in order to switch the battery from charging mode to discharging mode and vice versa [2].

Problem Identification And Research Objectives

There are following problems that has been identified in this work. They are as follows:

- The control of the PV-Hydro micro-grid (without storage battery as shown in Fig.1 becomes ineffective with the use of the ELC.
- During day time generated Power could be > consumer's load and excess power need to be wasted in dump load for frequency control
- The PV-Hydro Micro-Grid may not fulfill peak load demand during evening time when there is no power generation from PV plant.
- Instead of wasting energy in the ELC dump load, it can be stored in the battery bank, it can be used during peak load period and the load demand can be managed (as shown in Fig.2).
- In this system, ELC consumes excess power and do not allow to store energy in Battery. Hence, ELC shall be removed and new control logic shall be developed.

The objective of the research is as follows:

- To develop simulation model of a PV-Hydro micro-grid with battery backup system controlled through bi-directional converter to balance the power during off peak and peak load periods.

Proposed Approach

The main idea of our project is to connect PV and Hydro system in a common micro-grid bus along with a storage battery system that will act as a ELC for our scheme and will also act as a source during peak load period supplying the demand as per the requirement while maintaining the rotor and voltage stability.

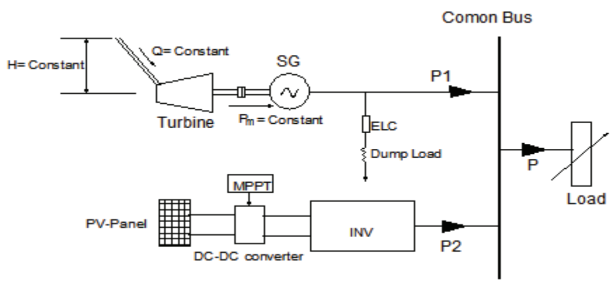

Figure 1: PV-Hydro Micro-Grid Without storage Battery.

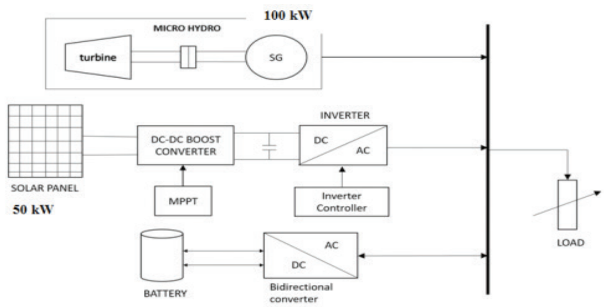

Figure 2: Proposed block diagram of the PV-Hydro micro-grid with battery storage system controlled through bidirectional converter.

ELC and dummy loads are used in the micro-grid system for the management of the power which is considered to be inefficient scheme. Thus, the solution for the efficient management of the energy is by using a battery bank with the bidirectional converter. A battery bank can be connected to the micro-grid with the bidirectional converter acting as a controller for the power storage during the excess generation and power source during the peak demand. Thus battery acts as a load as well as source depending upon the demand and supply/generation.

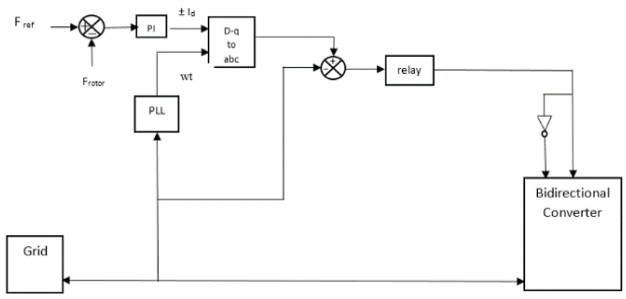

Figure 3: Proposed block diagram of the AC-DC Bidirectional Converter

Methodologies

- Simulation and monitoring of the PV system using the MPPT algorithm [3].
- Simulation and monitoring of the Micro-hydro plant.
- Synchronizing PV and Hydro in a common micro-grid bus.
- Simulation and monitoring of the battery source using the bidirectional converter.
- Studying and implementing all the system in a common micro-grid system and controlling the system.

Discussion

In contemporary energy management systems, a battery backup system with a bidirectional converter is a must. This advanced converter ensures effective use of energy resources by facilitating smooth power transfer between various sources and loads. The bidirectional converter effectively distributes extra energy to charge the batteries during periods of surplus power, such as when renewable sources or the grid are producing more electricity than needed. In contrast, it smoothly transitions to releasing the stored energy from the batteries to power essential loads when demand exceeds supply or during power outages. In addition to improving grid resilience, this dynamic bidirectional capacity makes it easier to integrate renewable energy sources by maximizing their use and facilitating grid interaction. Bidirectional converters guarantee reliable operation and robust performance with sophisticated control algorithms. In the proposed bidirectional converter scheme, the reference speed and actual speed of the rotor is sensed and the error is fed to the PI controller in the control logic. The PI controller generated the required Id based on the error. The obtained Id is then transformed to I_{abc} through the inverse park transformation and by tracking the current through the hysteresis band current controller we obtain a gate signal to switch the IGBT converter. The IGBT converter acts as a three-phase inverter as well as three phase rectifiers depending upon the control signal generated by the control logic. Thus, battery will gets charged whenever there is negative Id generated from the PI controller. The negative Id means excess of power in the grid and power flows inward. At, this condition the IGBT converter acts as a rectifier. But at peak load period, whenever the grid is in need of power the PI controller generates the positive Id the battery comes in discharging mode and the IGBT converter acts as Inverter which supplies power to the grid.

Various modes of Operation:

Mode-1: Power Flow from DC grid to AC grid:

When Power available from main grid > Load 11

- Excess of power is utilized to charge the storage battery through the bi-directional converter.

Mode-2: Power Flow from AC grid to DC grid:

When Power available in the main grid < load

- The battery acts as a source and supplies the load with the required power through the bi-directional converter.

The Bidirectional converter with the storage battery system could replace the use of dummy load. In this system the excess of the energy is stored in the battery while maintaining the rotor and grid stability while the stored energy could be again utilized at the peak-load period or that period whenever the overall system is generating less amount of energy then the required load [4]. For this bi-directional scheme that has been implemented plays a very important role in maintaining the rotor as well as voltage stability in the grid and allowing the power conversion between the battery and the AC grid system [5].

Observation and Results

Following table and plot shows the results of the model that has been simulated in the MATLAB Simulink software and they are as follows:

Table 1: Power supplied to the load before and after the switching of circuit breaker.

S/N	Source of power	Power generated between 0 to 30 seconds	Power generated after 30 Seconds
1.	Photo Voltaic system	50KW	50KW
2.	Micro-hydro system	100KW	100KW
3.	Battery Storage System	-50KW (Charging)	50KW (Discharging)
4.	**Load Power**	**100KW**	**200KW**

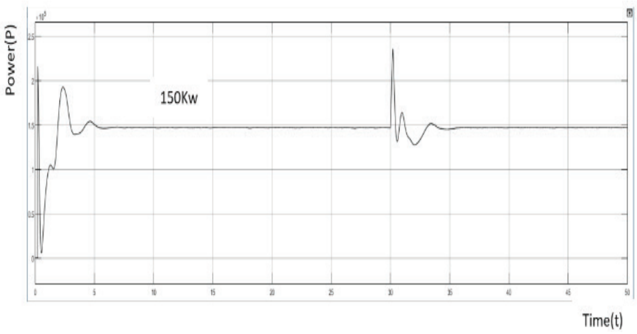

Figure 4:Power generated by PV and micro-hydro combined.

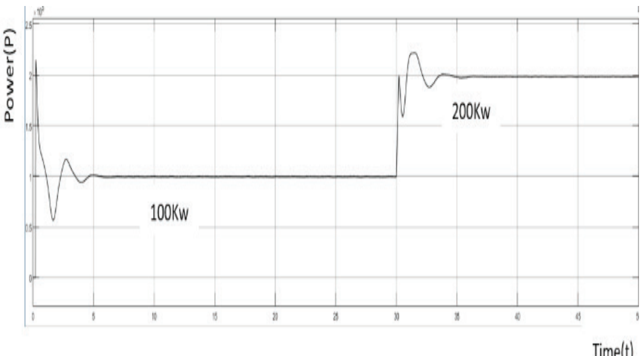

Figure 5: Power consumed by the load at differently loaded condition.

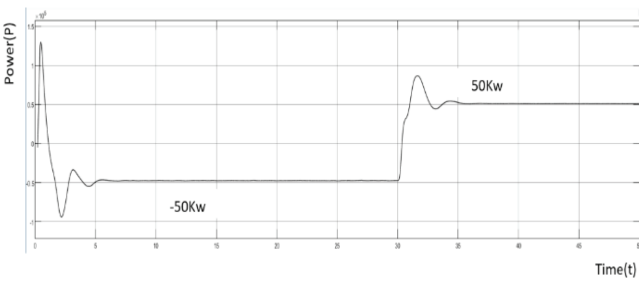

Figure 6: Power through battery storage system controlled through the bidirectional converter.

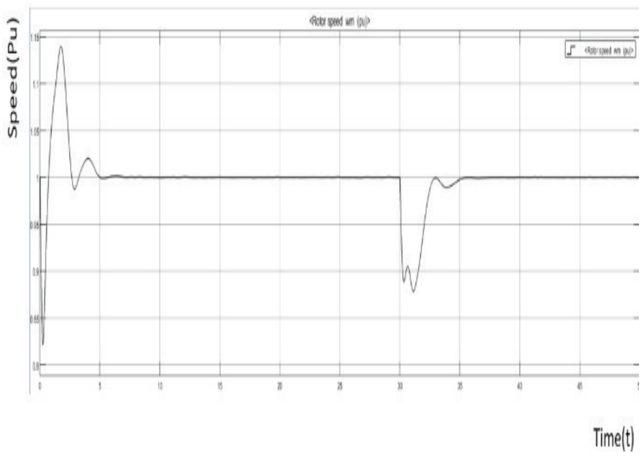

Figure 7: Speed control of the rotor of the alternator in micro-hydro plant before and after the addition of the load.

Initially, from t=0 sec to t=30 sec when the load is 100KW at that time the ESS acts as a load and consumes the surplus power from the grid i.e. 50KW in this case. After t=30 sec, when the additional 100KW is added the total load becomes 200KW where 150KW is supplied by the PV + Micro-Hydro while remaining 50KW is supplied through the energy storage system connected via bidirectional converter. Thus, the storage battery system is acting as a load and source simultaneously in order to create a power balance in the micro-grid.

Conclusion

Thus, with this scheme, it is possible to design a bi-directional converter system that manages the energy in the micro-grid during the light load period and peak load period by the use of energy storage system while acting as an ELC to maintain the rotor speed during differently loaded condition. Control of PV-Hydro micro-grid with energy storage system controlled through the bidirectional converter is achieved.

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