Mitigation of Multiple Voltage Dips in a Weak Grid Using Wind and Hydro-based Distributed Generation

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***Abstract*-- In the year 2007, South Africa experienced high demands of electricity power than that could have been generated. Due to greater demand than the generation, the country experienced planned and unplanned load shedding. Hence the commercial operations, industrialization country's economy and mostly people's life styles were highly affected. The unplanned load growth, indiscriminate integration of distributed generation by consumers and power companies and faults on the system has resulted in poor power quality problems such as voltage dip among others. At the present time distributed generation (DG) has been experiencing a rapid development in a global scale. The size of hydroelectric plant and wind farms are increasing quickly and a large amount of renewable distributed generation is integrated into the grid daily. This paper presents the modeling and simulation of schemes with wind energy conversion systems (WECS) and hydroelectric plant (HP) for mitigation of multiple voltage dips within a short period of time on power system. The schemes are simulated using DIgSILENT Power Factory and the applicability of the WECS and HP as regard to mitigating multiple voltage dips are evaluated and compared within a short duration and from different fault locations.**

***Index Terms*-- distributed generation, hydroelectric plant, weak grid, wind energy conversion systems, voltage dips.**

I. Introduction

One of the most important infrastructures in any country is energy. This has become a basic need for man to live. As the population over the years have increased, and the demands for electricity have grown, utilities around the world, face the problem of electrification and delivery of reliable and quality electricity.

Due to various pressures such as regulatory bodies, cost of constructing large power plants, environmental impact issues, competitive markets, and the concept of centralized generation is becoming more difficult to implement[1], [2]. As a result of these, there is a strong need for cleaner renewable energy sources. Distributed generation (DG) is one of the new technologies that are bracing electrical networks around the world. In United Kingdom there is a set goal to raise the generation of electricity from renewable resources up to 15% in 2020 and the United States (US) has planed that 22% of new installed generation capacity should be from distributed generation by the year 2020 [3].The United States is expected to provide 20% of nation's electricity only from wind energy by 2030 [4]. Also in Japan, projection of the electricity substitution by renewable energy in 2050 would be 10 % for wind power, 18 % for solar energy, 14 % for biomass, 10 % for geothermal heat and 14 % for hydraulic power [5].

In the African context, especially in South Africa, many low income households make use of traditional forms of energy such as animal dung, paraffin, wood and coal to meet their daily energy needs despite the fact that abundant natural resources of cleaner energy available. For example, solar energy is abundantly available especially in the north western part of South Africa where some of the best solar irradiation in the world can be found. Besides, the wind energy in the northern, Eastern and Western Cape provinces has the potential to generate a number of Gigawatts (GW).

The number of renewable energy projects in South Africa is still extremely limited given the abundant resources available and the profile that the renewable energy as a source of clean energy is receiving worldwide. The main reason for this is that, as a developing country, South Africa has been focusing on cheap energy from fossil fuels, in particular electricity from coal-fired power stations leading to very high emission levels. Total dependence on this is not advisable for a developing nation. There is a need to diversify the energy sources to renewable energy such as wind, solar and small hydro power for sustainable energy development. This will reduce the effect of green house gas produced from burning fossil fuel that is manifesting more and more and subjecting the environment to global threat. When these renewable energies are implemented as Distributed Generation (DG) it is expected to play an important role in the operation of power network.

In a normal, healthy power network, the power generated must be equal to the load demand at any particular point of time. Any reactive power imbalance in the system disturbs the voltage at the load points and the voltage profiles along the network. This imbalance or sudden change causes unexpected drop in the voltage in a power network and is known as voltage dip. This paper is set out to model the wind energy conversion systems and hydroelectric plant and investigate their response individually and combined to mitigate multiple voltage dips within a short period of time on power system. It also assesses, compares similarities and differences of these two deference types of distributed generators.

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978-1-4673-1935-5/12/$31.00 ©2012 IEEE

II. Definition of Voltage Dip Phenomena

Voltage dip has been a burning technical issue in South African weak power grid in the past few years resulting in poor power quality and stability. In recent times many industries and other consumers of electric power have lost so much revenue due to this difficult situation. Weak grids are usually found in most remote places where the feeders are long and operated at a medium voltage level. The grids in these places are usually designed for relatively small loads. When the design load is exceeded the voltage level will be below the allowed minimum voltage which leads to voltage dip in many cases.

Today a large number of customers and power producers complain about the power quality problems especially those caused due to voltage dips which has been regarded as the most costly power quality problem. Each year in the United States voltage dips and interruptions cause major economic damage and is estimated to be between U.S. $ 104 billion and U.S. $ 164 billion [6].

Voltage dip is a reduction in voltage magnitude below a dip magnitude threshold with duration typically from several cycles to several seconds [7]. It is also defined as a sudden short duration reduction of the voltage at the point of supply (nominal system voltage) to a value between the ranges of 10% to 90% of nominal voltage magnitude and with duration from 10 ms up to one minute. It might originate from switching of motors, generators, arc furnaces, transformers or from short circuits faults in power transmission and distribution system [8]. A voltage dip is characterized by its magnitude and duration. In most cases, fault types, source and fault impedances define the dip magnitude, whereas fault clearing time defines the dip duration.

An example of a typical voltage dip is shown in Fig 1a. It commences when the declared voltage drops to a lower voltage than the threshold voltage V_{thr} (0.9 p.u. or 90 %.) at time T1, it continues up to T2 at which the voltage recovers to a value over the threshold value. The magnitude of the voltage dip is V_{dip} and its duration is T2-T1 [9].

The harmful effects of voltage dip have caused serious problems for power quality-sensitive loads such as adjustable speed drives, process control equipment, computers, particularly in situations where delicate industrial processes demand a high quality voltage supply.

Many consumers have been using their own gadgets to solve the problem of voltage dips at their own premises. But this do not really solve the problem completely especially when there is a dip less than the gadget rating. At a very low voltage, voltage dip mitigation equipment such as voltage stabilizer can be used to deal with voltage dip. In this case, no energy storage mechanism is required. The automatic voltage stabilizers rely on generating full voltage from the available energy supply at reduced voltage during the dip. A few examples include, electro-mechanical, ferro-resonant or constant voltage transformer (CVT), electronic step regulators etc. [10].

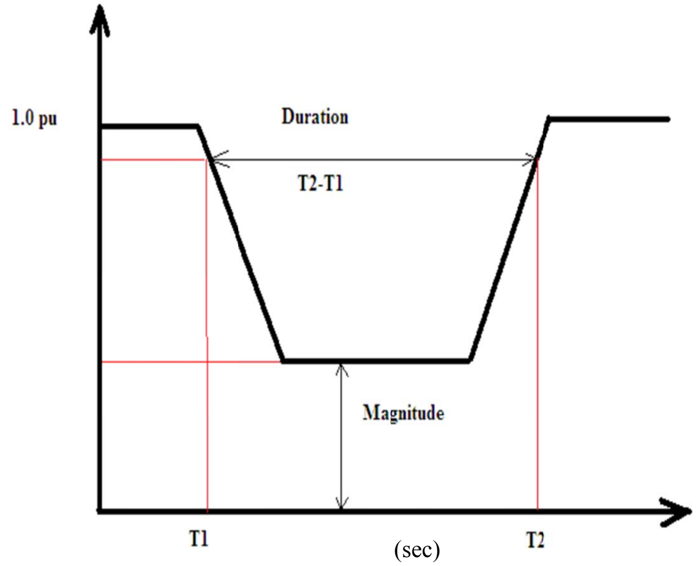

Fig 1a: Voltage dip (Courtesy: Ref [9])

In solving the problem of voltage dips and for keeping the voltage at its nominal value during the dip on the transmission and distribution power network, several methods or schemes have been proposed by various researchers. Many of these schemes utilize DG for improving the power quality, especially for mitigating voltage dip problems. Some DG schemes include series compensation and transfer to microgrid operation during dips reported by K.J.P. Macken et al. [8] and application of converter-based DG, synchronous and asynchronous generators suggested by B. Renders et al. [11].

III. Definition of Distributed Generation

In recent times the penetration of wind energy conversion systems (WECS) and hydroelectric plants (HP) into the grid for clean energy generation is significantly increasing and consequently their impact on grid operation are becoming more and more important. Power electronic interfaced wind generators connected to the grid can inject harmonic current which might deteriorate the power quality of the power system network [12]. It is well known that most wind generators also contribute to voltage disturbance on the grid, especially voltage dip. On the contrary distributed wind generators and hydroelectric plants when properly integrated can also be used to mitigate voltage dips in a power network.

Most countries of the world have been trying to reduce the carbon dioxide emissions and generate electrical power through the use of renewable DG such as WECS, HP, solar photovoltaic, etc. In technical literature, the term DG is synonymous with on-site generation, dispersed generation, embedded generation or decentralized generation, and is generally defined as any generation which is connected directly into the distribution network, as opposed to the transmission network. It makes use of small-scale low carbon