Emergency Power For Wind Turbine Yaw System

Project initialization tool

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June, 2020

***Abstract*—A safety backup system is required to be implemented in Wind Power Plants (WPP), in order to provide emergency power during a main power outage. The Yaw Power Backup System (YPBS) enables the Wind Turbine Generator (WTG) to perform a yawing operation in extreme weather conditions, reducing the acting forces from the wind and ensuring safety to the WTG. The purpose of this project is to develop a synthesis tool that estimates the ratings and cost of the components and to create a responsibility matrix that identifies the work activities and responsibilities during construction and service phase for the YPBS project. The studies include different models and sizes of WPP and WTGs. The tool is validated by simulations in DIgSILENT PowerFactory and Caterpillar SpecSizer. The results indicate that the synthesis tool is estimating reliable ratings and the components are operating within the safety requirements. The responsibility matrix is created and will be implemented in future projects.**

I. Introduction

WIND energy makes up an increasingly larger part of the energy mix and is the fastest growing source of renewable energy. The increasing demand for renewable energy has resulted in manufacturers to increase the WTG size and capacity. Higher towers result in the WTG becoming more sensitive to wind power forces and can obtain great damage during extreme weather conditions. Stresses can be reduced on the blades and its structure by aligning the rotor to track the incoming wind. During extreme weather conditions power outages can suddenly happen and without power backup supply, the WTG would obtain great damage resulting in serious consequences for the energy sector and financial losses.

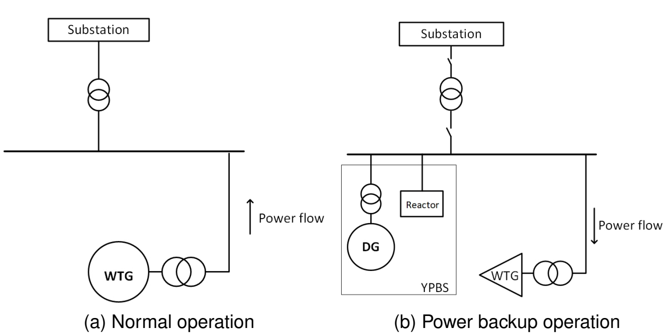

Fig. 1. YPBS implemented in WPP

The YPBS consists of a central placed emergency generator. A step-up transformer that transmits power from the generator to the internal electrical system of the WPP network and a shunt reactor that provides voltage control by compensating for the capacitance in the internal cable system. During normal operation (figure 1a) the WTG is generating electric power from wind energy, this power is collected and transmitted to the power transmission system via the substation. During a power outage the internal grid in the WPP is disconnected to the substation and the WTG is not generating power. The YPBS installed in the WPP (figure 1b) will ensure that sufficient power is supplied to components that are active during power backup operation, enabling the WTG to yaw.

This article gives a summary of the master's thesis Emergency Power for Wind Turbine Yaw System, which studies different operating conditions, models of WPP and selection of components to increase the reliability and accuracy of the synthesis tool.

II. Power backup system

A Power Backup System (PBS) is a generating source of power that supplies an electrical system in case of power failure. PBS based on Uninterruptible Power Supplies (UPS) and generator with reciprocating engine (genset) is the most common way to ensure continuity of operation [1]. The requirement for stored energy in a PBS is determined by the tolerated duration of power interruption, the quantity of power supply and the type of load.

A. UPS

UPS systems are designed to provide instantaneous power for a shorter power outage to protect critical loads by supplying energy typically stored in batteries. The battery size directly impacts the stored energy capacity and defines the output power and duration capability. Therefor UPS systems with batteries are often used during the initial seconds that it takes for the genset to start and become operational [2]. During this short period UPS will protect sensitive equipment and provide possibility for a safe and orderly shutdown.

B. Genset

Genset has the capability to restore power from a shutdown condition to an operating condition and supply high power for an unlimited period of time. They can be designed to run as a standby or a continuous power supply unit, with the ability to start automatically and run at full capacity within 10 seconds of power failure. [2]. A genset with a diesel engine and a synchronous generator, known as a diesel generator (DG) is the most used technology for high power demand, due to accessibility, power density, running capability and cost [1].

C. The YPBS

For a WPP with 60 WTGs, the loads can require up to 10.5 MVA from the power source during backup operation. A combination of cost and the demand for high power supply during longer periods of time, results in the selection of a genset for the YPBS.

III. Initialization Tool

The synthesis tool is developed in Microsoft Excel due to its accessibility. In order to carry out the purpose of the work, guidelines of deriving and dimensioning the complementary parts of the backup system are explored. Data and requirements are gathered for WTG models and auxiliary loads. The tool considers information about the WPP as input and return the recommended size for the YPBS components as output.

The tool is divided into two main sections, considering a fixed rating shunt reactor with no-load tap changer (NLTC) and a variable shunt reactor with on-load tap changer (OLTC). For each section the tool will consider operating conditions for starting and running loads. Based on information gathered from load flow simulations and sequential start analysis, a final recommendation of the components size is presented.

IV. Responsibility matrix

Responsibility Assignment Matrix (RAM) is a chart with a simple structure to describe the stakeholders participation for each specific work section in the project. The RAM is acquired by understanding the responsibilities for the work activities by interviewing and setting workshops with stakeholders within and outside the organisation that are involved in the YPBS project. For YPBS project the RACI model is used and the acronym stand for Responsible, Accountable, Consulted and Informed. Each representing a level of responsibility for a work activity. A sample of RAM using the RACI model is illustrated in table I adopted from [3]. The first step is to identify each work activity for the execution and service phase of the YPBS project. An overview of the main activities are presented in figure (2), and includes as initial phase to create the functional design document to the finalisation service phase of the YPBS project.

TABLE I
RAM using RACI model

Activity \ Person	Ann	Ben	Carlos	Dina
Requirements	R	C	A	I
Design	A	R	I	C
Develop	I	A	R	C
Test	I	R	R	A

The stakeholders involved in the YPBS project for execution and service phase are presented in figure 3. Power Plant Solutions team (PPS) is responsible for the electrical grid system. SCADA team provides solutions to implement the control configuration for the systems to be able to communicate with each other. Construction team is in control of the management and coordination of activities. Service team performs the maintenance of the components. Grid integration performs analysis of the grid. Supplier designs and manufactures the YPBS components.

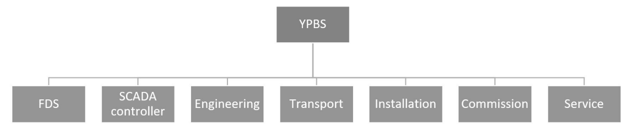

Fig. 2. Work activities for the YPBS project

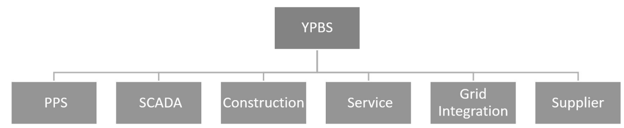

Fig. 3. Stakeholders for the YPBS project

V. Simulations

A. PowerFactory

The goal of the load flow simulations is to validate if the purposed ratings from the tool are fulfilling the requirements for the power system operation steady state conditions:

- Generator to operate within its stability limits
- Generator to supply power to the demand
- Voltage magnitude to remain close to rated values

The PowerFactory models consider six WPPs with 6-60 WTGs, only power source is the backup DG. The DG supplies power from low-voltage to medium-voltage via the YPBS transformer. The WTG load is represented as a low-voltage load with WTG transformer connected to medium-voltage. Two scenarios have been investigated for the six WPPs, with a traditional fixed shunt reactor or a variable shunt reactor applied. For each scenario, two operation conditions have been investigated, maximum load condition and no-load condition. First condition considers that all the WTGs are performing a yawing operation simultaneously, resulting in max load for supply of total demand. Second condition represents that all WTGs are disconnected, the only connected loads are auxiliary loads. The interval between these two conditions will represent the total power requirement for the DG.

B. SpecSizer

In SpecSizer a study case is analysed to validate the impact of the DG size when the asynchronous yaw motors in the WTGs are sequentially energized. The study case represents a WPP with three radial feeders and six WTGs connected to each feeder. Three cases are considered (Table II), in the first case all the WTGs are simultaneously energized. Second case is divided in two steps. First step, energizing the WTGs in feeder one and two, in second step energizing the WTGs in feeder three. In the third case the energization of the WTGs is divided into three steps, in each step the WTGs in the representing feeder are energized.

VI. Results

A. SpecSizer sequential starting analysis

Table II shows a summary for the three cases. Sequential starting reduces the total inrush current during the starting phase of the yaw motors in the WTGs. The results indicates that a DG of less size could be selected if the starting sequence is divided in several steps. The load factor of the DG should exceed 30 % to prevent negative impact to the unit, when running in extended time periods [4]. Energizing the WTGs in steps would result in a DG that is operating more optimal with 50-80 % load factor. For the recommended DG, the typical transient recovery when applying an instantaneous load change of 100 %, would take about 4.5-6.8 seconds. If the start-up sequence is managed in steps, the time frame for starting all at once or in three steps, is at most two times greater. The analysis results show that starting power of the asynchronous motors in the yaw system could exceed the rating of the DG.

TABLE II
Sequential starting analysis results

Load step analysis in SpecSizer	DG rating (kVA)	Maximum transient peak (kVA)	Final running load (kVA)	DG capacity used (%)	Typical recovery time (seconds)
Case 1	1825	2538.7	607.5	33.5%	6.8
Case 2	1150	1692.5	607.5	52.8%	6.2
Case 3	770	1180.2	607.5	79.1%	4.5

B. PowerFactory load flow simulations

Figure 4 illustrates the operating points for the DG with fixed shunt reactor applied, for the two operating conditions. The limitation of a fixed reactor rating will result in an oversized reactor when in maximum load condition and undersized when in no-load condition. The DG will have to generate reactive power to compensate for the surplus of reactive reserve in the system as a result of the oversized reactor. During no-load condition the DG is absorbing reactive power to compensate for the capacitance of the underground cable system dominating the inductive load.

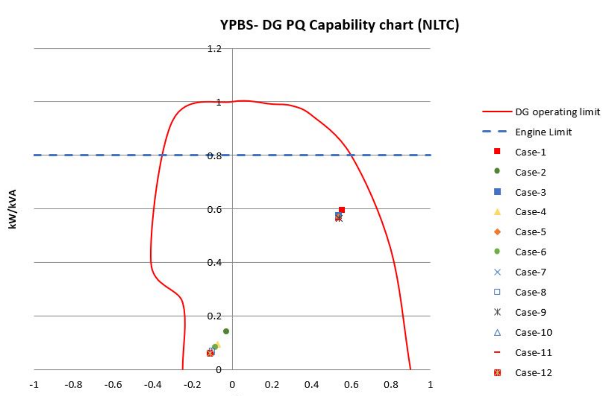

Fig. 4. Generator operating points in the capability chart with fixed shunt reactor applied

Figure 5 illustrates the operating points for the DG with variable shunt reactor applied. During maximum load and no-load condition the shunt reactor is compensating for the cable capacitance. The DG is mainly generating active power with nearly constant voltage rating.

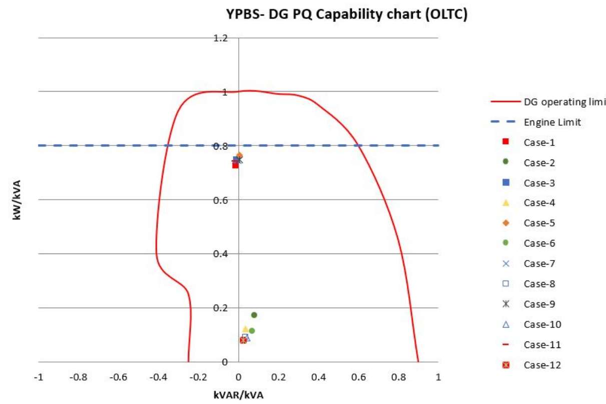

Fig. 5. Generator operating points in the capability chart with variable shunt reactor applied

VII. Conclusion

The simulation study cases with recommended ratings from the tool, indicates that the YPBS components are operating within their stability limits and fulfilling operation requirements. This indicates that the tool can be used for the initialization phase of the YPBS projects. The responsibility matrix is created with the activities and corresponding responsibilities for the YPBS project. The matrix is agreed on by all involved stakeholders and will be implemented in future projects. When a variable shunt reactor with OLTC is applied, the DG will operate more efficiently and the installed capacity can be reduced by 25 %. Implementing sequential starting of the yaw motors would reduce the inrush transient and result in a reduction of the DG size by a factor of 2.4. Resulting in cost reduction at approximately the same rate.

References

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[4] B. Jabeck, “The Impact of Generator Set Underloading,” Oct 2013.

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