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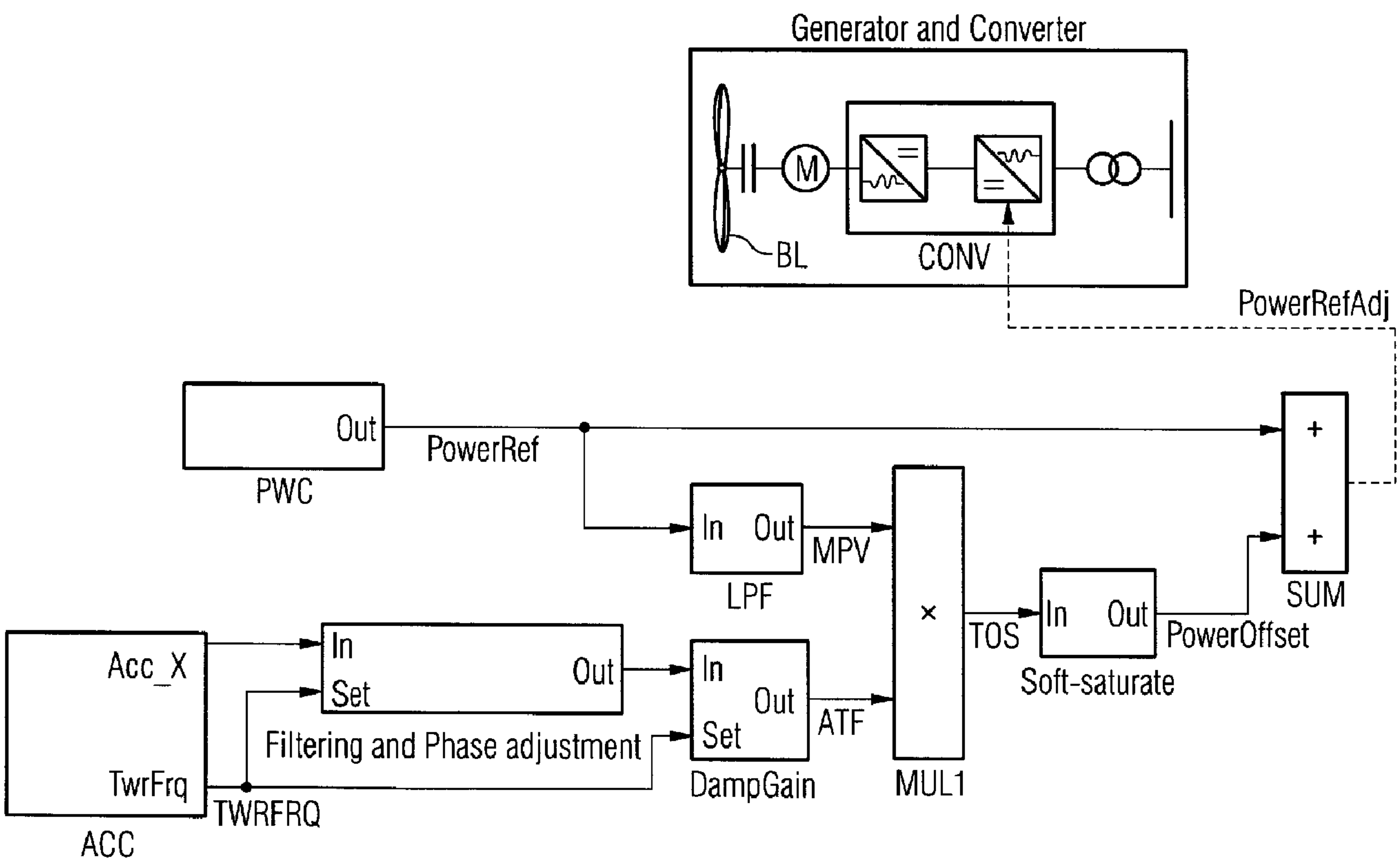
(54) Titre : METHODE ET MONTAGE D'AMORTISSEMENT DES OSCILLATIONS DE TOUR

(54) Title: METHOD AND ARRANGEMENT FOR DAMPING OF TOWER-OSCILLATIONS



(57) Abrégé/Abstract:
The invention relates to a method and an arrangement for damping of tower-oscillations. According to the inventive method for damping of tower-oscillations a rotation is transformed into electrical power by a generator (M), which is located on top of the tower. The electrical power is transformed from AC to DC and back to AC by a converter (CONV). A power-reference-signal (PowerRef) is used by the converter (CONV) to control the delivered electrical power. A variable power-offset-signal (PowerOffset) is added to the power-reference-signal (PowerRef), before it is used for control. The variable power-offset-signal (PowerOff-set) is based at a mean value of the power-reference-signal (powerRef) and is based at a side-by-side-oscillation of the tower.

Abstract

Method and arrangement for damping of tower-oscillations

The invention relates to a method and an arrangement for damping of tower-oscillations.

According to the inventive method for damping of tower-oscillations a rotation is transformed into electrical power by a generator (M), which is located on top of the tower. The electrical power is transformed from AC to DC and back to AC by a converter (CONV). A power-reference-signal (PowerRef) is used by the converter (CONV) to control the delivered electrical power. A variable power-offset-signal (PowerOffset) is added to the power-reference-signal (PowerRef), before it is used for control. The variable power-offset-signal (PowerOffset) is based at a mean value of the power-reference-signal (powerRef) and is based at a side-by-side-oscillation of the tower.

FIG 1

Description

Method and arrangement for damping of tower-oscillations

The invention relates to a method and an arrangement for damping of tower-oscillations.

Especially the invention relates to a tower of a wind-turbine, which wears a nacelle on top.

If a wind-turbine tower is oscillating there will be the effect of tower-movements. This results to a big load, which acts on a mounted yaw-system of the wind-tower, on a gear within the wind-turbine nacelle and on the tower itself.

It is known to reduce this effect by a so called "active damping" of the tower oscillation.

The US 7,309,930 B2 describes a solution to damp vibration based on a controlled torque. A vibration damping system for the wind-turbine is mounted on the tower. The vibration damping system comprises a vibration damper, which uses a variable signal to control the torque. The variable signal is based on a speed of a generator.

Another way to deal with tower oscillations is to design relevant mechanical constructions strong enough to tolerate extra forces, which are induced by the tower-movements.

Additionally relevant spear parts have to be changed more often because of wear and tear.

It is the aim of the invention, to provide an improved method and arrangement for the damping of tower-oscillations of a wind-turbine.

This problem is solved by the features of claim 1 and 8. Preferred embodiments of the invention are subject of the subsequent claims.

According to the inventive method for damping of tower-oscillations a rotation is transformed into electrical power by a generator, which is located on top of the tower. The electrical power is transformed from AC to DC and back to AC by a converter. A power-reference-signal is used by the converter to control the delivered electrical power. A variable power-offset-signal is added to the power-reference-signal, before it is used for control. The variable power-offset-signal is based at a mean value of the power-reference-signal and is based at a side-by-side-oscillation of the tower.

According to the invention a power-set-point is changed in that way, that a torque of the tower is oscillated with another power. This power shows the same frequency as the tower oscillations but shows an adapted phase-shift. The phase-shift is adapted in that way, that the tower oscillations are reduced, so typically a phase-shift of 180° is used.

The tower oscillations or vibrations are measured by a G-sensor in a preferred embodiment, while this sensor could be placed on top of the tower or within a nacelle of a wind-turbine, etc.

The signal of the sensor is filtered and delayed to get the optimized phase-shift. Then the phase-shifted-signal is multiplied with a mean power-reference-signal, to ensure that the power of the signal to be used to damp the tower will scale with the mean power-reference-signal.

The damping signal is then added to the power-reference-signal before it is used for control of the converter.

The signal generated by multiplication is saturated with a soft-saturator-function in a preferred embodiment. This is done to ensure that the amplitude of the signal is not to large as this would result in damaging the wind-turbine or would result in large loads in the wind-turbine. Because of the soft-saturation harmonics of the tower frequency are avoided.

In the prior art mentioned above the generator speed signal is a vital part of the control system to dampen the vibrations of the tower. By using the torque as reference as it is within the US 7309930 B2 for the damping power reference, the relation between damping power reference and mean power reference will increase, when the mean power is decreasing and the rotor speed is constant. This results in high flicker level at the grid. In contrast to this the inventive method leads to a less flicker level at the grid successfully.

An advanced improvement by adjusting the power-reference-signal by multiplication as it is within this inevntion is, that the adjusted power-reference-signal shows a constant relation to a mean power signal.

The invention is described in more detail with help of a drawing.

FIG 1 shows a block-diagram of the inventive method for the damping of tower-oscillations, and

FIG 2 shows with reference to FIG 1 an exemplary possibility to generate a soft-saturator-function.

Referring to FIG 1 a nacelle of a wind-turbine wears a number of blades BL to rotate within the wind. The resulting rotation acts on a generator or motor M, where the rotation is transformed into electrical power.

The frequency varying AC power is transformed into a static frequency to match a connected grid. This transformation is done by a converter CONV, which is a combination of a generator inverter and a grid inverter.

The generator inverter converts AC to DC. The grid inverter converts the DC back to AC with a frequency, which is matching to the connected grid.

A power controller PWC is used to adjust an obtained electrical power from the rotation up to a rated power-value. This control is done by the use of a power-reference-signal powerRef, which is brought to the converter CONV.

If the rated power-value is reached, the power-reference-signal powerRef is kept constant.

The power-reference-signal powerRef of the power-controller PWC is brought to the converter CONV via a summation-unit SUM. By help of the summation-unit SUM the power-reference-signal powerRef is modified before it reaches the converter CONV. So the power-reference-signal powerRef is brought as a first input-signal to the summation-unit SUM.

The power-reference-signal powerRef is also used to generate a second input-signal for the summation-unit SUM for the modification.

The power-reference-signal powerRef is brought to a low-pass-filter LPF, too. The low-pass-filter LPF calculates a mean-power-value MPV in dependency of a chosen time interval. Typically a few seconds are used as time interval.

The calculated mean-power-value MPV is brought as input signal to a first multiplication-unit MUL1.

There is an accelerometer ACC, which is used to measure a vibration signal of the tower. For example a so called "G-sensor" could be used for this purpose, to be placed on the top of the tower or within the nacelle of the wind-turbine.

But this vibration-signal is interfered by other signals like noise, so a unit "filtering and phase adjustment" has to be used to remove the interfering signals from the measured vibration-signal.

According to this an acceleration-signal Acc_X and a tower-frequency-signal TWRFRQ are measured and are used to adjust a filter and a delay setting of the unit "filtering and phase adjustment".

So the unit "filtering and phase adjustment" generates an output-signal to be used as input-signal for a unit "DampGain".

The unit "DampGain" is used for an amplitude-adjustment of its input-signal to generate a signal, which represents the acceleration-signal Acc_X with an usable amplitude for calculations needed later.

This leads to an actual tower-frequency ATF, which is brought as input-signal to the first multiplication-unit MUL1, too.

The first multiplication-unit MUL1 calculates a tower-oscillating-signal TOS as output-signal. This tower-oscillating-signal TOS is saturated by a unit "soft-saturate", which shows a so called "soft-saturator-function" as described now. Because of the saturation an output-signal PowerOffset is built by the unit "soft-saturate".

The soft-saturator-function has a gain, which is adjusted dynamically between 0 and 1. If peak-values of the tower-oscillation-signal TOS reach a predetermined saturation-limit, the gain is reduced. So the output-signal PowerOffset is kept under the saturation-limit.

The gain is raised dynamically step by step again, if the peak-values of the tower-oscillation-signal TOS are reduced.

The soft-saturator-function is described later exemplary by help of FIG 2.

The power-reference-signal powerRef and the output-signal PowerOffset are summed up by the summation-unit SUM to generate the modified power-reference-signal PowerRefAdj, which is brought to the converter CONV.

This adjusted power-reference-signal powerRefadj is now used to control the converter CONV as described above.

FIG 2 shows with reference to FIG 1 an exemplary possibility to generate the soft-saturator-function.

An output-signal OSS of a multiplication-unit MUL is brought as input-signal to a saturation-unit SAT. This unit SAT saturates the signal OSS to define its maximum level leading to an output-signal outs.

A difference signal DIFF between the signal OSS and the signal outs is calculated by a first deviation-unit DEV1. Later the absolute value of the difference signal DIFF is calculated and the result is multiplied by a factor "K" to calculate a steering-signal SS.

The factor K represents how fast the signal OSS is to be decreased.

The steering-signal SS represents the saturation of the signal OSS.

The steering-signal SS is brought as input-signal to a second deviation-unit DEV2. A release-time RT is brought as another input-signal to the second deviation-unit DEV2, too.

An output-signal of the second deviation-unit DEV2 is used to choose a reference-value RVV, which is brought via a memory-unit as input-signal to the multiplication-unit MUL and which is brought as input-signal back to the second deviation-unit DEV2.

The second deviation-unit DEV2 calculates a difference between their input-signals as shown.

The reference-value RVV will be "1" normally. If the saturation-unit SAT clips the signal OSS then the reference-value RVV is going to change towards "0".

Because of the described loop the reference-value RVV will lead to a decreased signal OSS. The reference-value RVV is used to avoid the clipping of the signal OSS within the saturation-unit SAT.

Patent claims

1. Method for damping of tower-oscillations,
   - where rotation is transformed into electrical power by a generator (M), which is located on top of the tower,
   - where the electrical power is transformed from AC to DC and back to AC by a converter (CONV),
   - where a power-reference-signal (PowerRef) is used by the converter (CONV) to control the delivered electrical power,

   characterized in,
   - that a variable power-offset-signal (PowerOffset) is added to the power-reference-signal (PowerRef) before it is used for control, and
   - that the variable power-offset-signal (PowerOffset) is based at a mean value of the power-reference-signal (powerRef), and is based at a side-by-side-oscillation of the tower.

2. Method according to claim 1, characterized in that the variable power-offset-signal (PowerOffset) is calculated by a multiplication of a first signal (MPV), which represents the mean value (MPV) of the power-reference-signal (powerRef), and a second signal (ATF), which represents the side-by-side-oscillation of the tower.

3. Method according to one of the preceding claims, characterized in, that the mean value (MPV) of the power-reference-signal (powerRef) is calculated in dependency of a chosen time interval.

4. Method according to one of the preceding claims, characterized in, that the side-by-side-oscillation of the tower (ATF) is destined
   - by measuring a vibration signal of the tower,
   - by removing interfering signals from the vibration-signal, and

- by adjusting the amplitude of the interference-free signal.

5. Method according to one of the preceding claims, characterized in, that the variable power-offset-signal (PowerOffset) is saturated without clipping before it is added to the power-reference-signal (PowerRef).

6. Method according to claim 5 and 2, characterized in that the soft-saturation is done
   - by calculation of a tower-oscillation-signal (TOS) by multiplication of the first signal (MPV) with the second signal (ATF),
   - by choosing a gain-factor to be multiplied with the tower-oscillation-signal (TOS),
   - by reducing the gain-factor dynamically, if peak-values of the tower-oscillation-signal (TOS) reaches a predetermined saturation-limit,
   - to keep the variable power-offset-signal (PowerOffset) under the saturation-limit.

7. Method according to claim 1, whereas tower-oscillations of a wind-turbine are damped.

8. Arrangement for damping of tower-oscillations according to the method of the preceding claims,
   - with a generator (M), which transforms rotation into electrical power,
   - with a converter (CONV), which is connected with the generator (M) and which transforms frequency varying AC power into a static frequency AC power to match a connected grid,
   - with a power controller (PWC), which is connected with the converter (CONV), so a power-reference-signal (PowerRef) of the power controller (PWC) is used to control the converter to adjust an obtained electrical power from the rotation up to a rated power-value,

characterized in,

- that there is a summation-unit (SUM) between the power controller (PWC) and the converter (CONV), which is connected with them to add a variable power-offset-signal (PowerOffset) to the power-reference-signal (powerRef) before it is used to control the converter (CONV), while the variable power-offset-signal (PowerOffset) is based at a mean value (MPV) of the power-reference-signal (powerRef) of the power controller (PWC) and is based at a side-by-side-oscillation of the tower (ATF), too.

9. Arrangement according to claim 8, characterized in, that the power controller (PWC) is connected with a first multiplier (MUL1), which calculates the variable power-offset-signal (PowerOffset) by multiplication of the mean value of the power-reference-signal (powerRef) of the power controller (PWC) with the side-by-side-oscillation of the tower.

10. Arrangement according to claim 9, characterized in, that the power controller (PWC) is connected via an unit for filtering (LPF) with the first multiplier (MUL1), while the unit for filtering (LPF) calculates the mean value of the power-reference-signal (powerRef) in dependency of a predetermined time-interval.

11. Arrangement according to claim 8 or 9, characterized in,
- that there is an accelerometer ACC, which is used to measure a vibration signal of the tower,
- that there is a unit for filtering and phase adjustment, which is connected with the accelerometer ACC, to remove interfering signals from the measured vibration-signal,
- that there is a damp-gain-unit, connected with the unit for filtering and phase adjustment, to adjust an amplitude of the interference-free vibration-signal, which represents the side-by-side-oscillation of the tower (ATF), and

- that the damp-gain-unit is connected with the first multiplier (MUL1), to calculate the variable power-offset-signal (PowerOffset) by multiplication.

12. Arrangement according to one of the claims 8 to 11, characterized in, that there is an unit for saturation between the first multiplier (MUL1) and the summation-unit (SUM) to saturate the variable power-offset-signal (PowerOffset) without clipping before it is used for the control of the converter (CONV).

13. Arrangement according to one of the claims 8 to 12, characterized in, that the tower is a tower wearing a wind-turbine or a nacelle.

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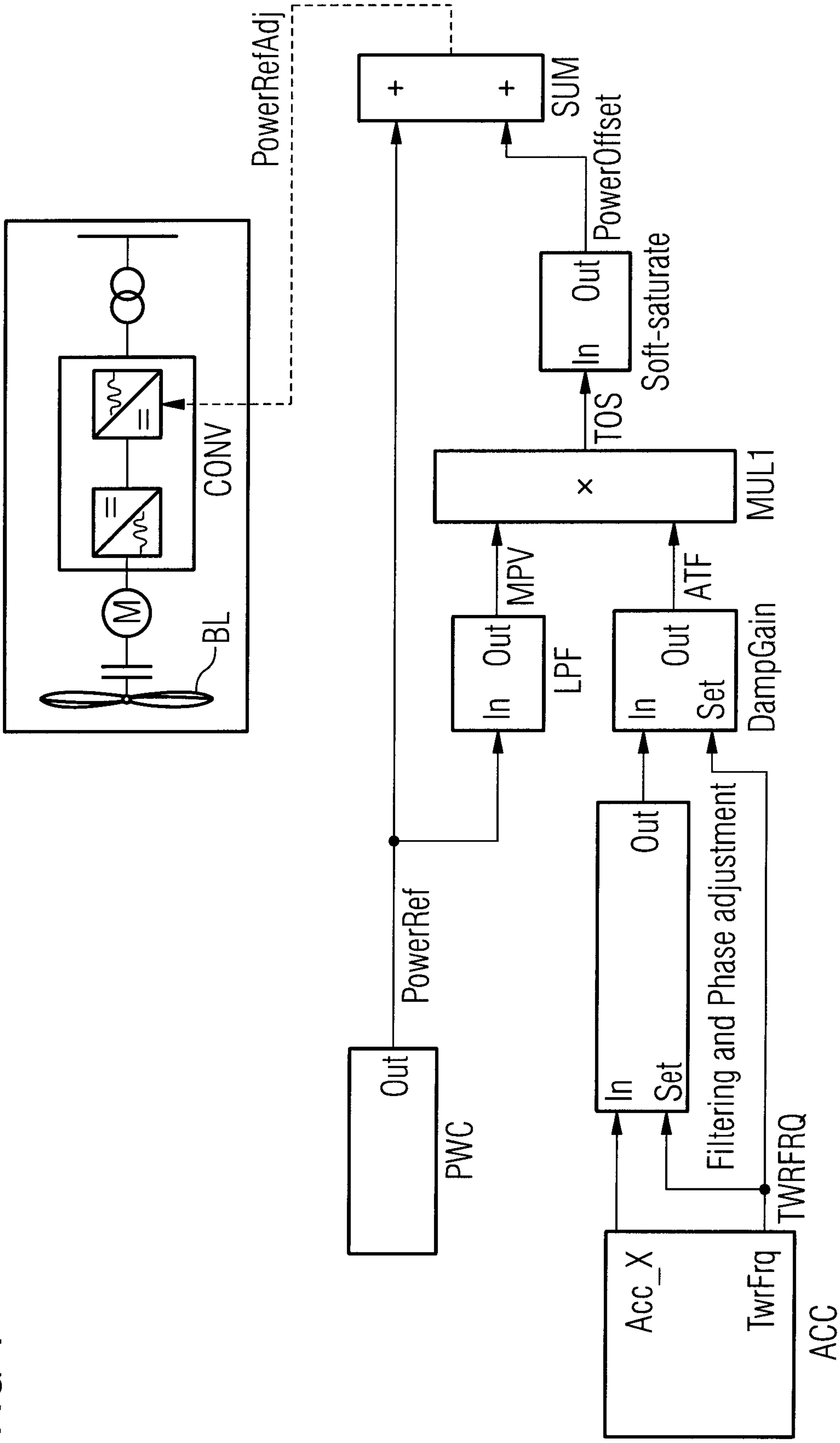

FIG 1

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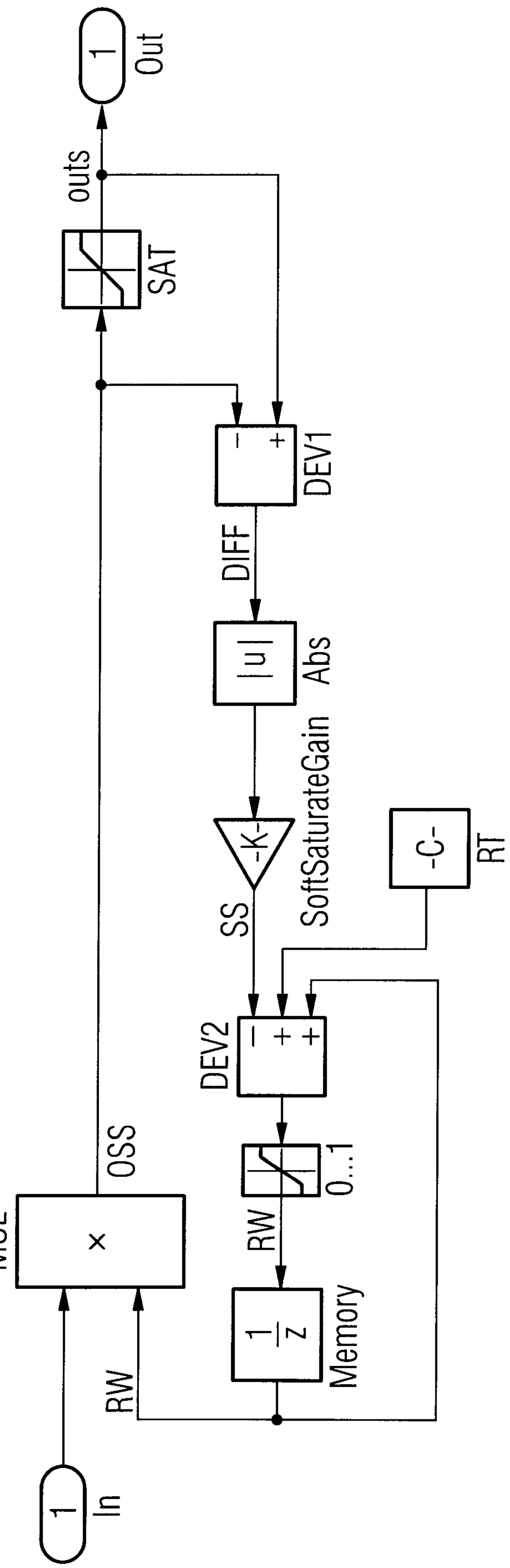
FIG 2




Generator and Converter
M
BL
CONV
PowerRefAdj
Out
PowerRef
PWC
In
Out
MPV
LPF
×
+
+
SUM
TOS
In
Out
PowerOffset
Soft-saturate
Acc_X
TwrFrq
ACC
TWRFRQ
In
Set
Out
Filtering and Phase adjustment
In
Out
Set
ATF
DampGain
MUL1