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COORDINATED CONTROL OF PSS AND TCSC ON DAMPING IN POWER SYSTEM USING MATLAB SOFTWARE

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Abstract:- *This paper will discuss about the damping occurs in the power system. Power systems are interconnected through the long distance tie lines. To transfer or exchange a large amount of electric power, transmission lines are used. For maintaining reliability and stability, the rotor angle stability is essential. The complete simulation of WSCC9 bus system with PSS and TCSC is shown in this paper. Generic PSS is used in all the three generators. Simulation is carried out in the MATLAB 2012 software. When electrical quantity is suddenly changes then mechanical quantity cannot change instantaneously because of its moment of inertia. Therefore in a small duration, the rotor of generator feels an oscillation that have to damp. By using PSS, local area mode and inter area modes of oscillations are effectively damp. But sometimes PSS fails to damp inter area modes of oscillation. By using coordinate control of PSS and TCSC controller, Local area and inter area modes of oscillation can be effectively damp.*

Keywords:- *WSCC9 bus system, PSS, TCSC, Local area mode, inter area mode and damping*

I. INTRODUCTION

Most power system are interconnected through long distance tie line in order to transfer a large amount of electric power. Stability, reliability and good performance are necessary in power system operation to guarantee a safe and continuous energy supply with quality. Due to shortage of funds to build new transmission Lines and also the demand for electric power has rapidly increased and is expected to continue growing , while expansion in generation is restricted. Due to the same reasons mentioned above, this necessitates the generators too to operate near their stability limits. Due to all these factors, power systems oscillations will occur; if not well damped, these oscillations may keep increasing until loss of synchronism.

In a practical system, the various modes of oscillation occur in the power system [15].

1) Intra plant mode:- The oscillation frequencies are so high in the range of 1.5 to 3.0 HZ. Intra plant modes in which only generators in power plant participate.
2) Local mode:- The frequencies of oscillation are in the range of 0.8 to 1.8 HZ. Local modes in which several generators in an area participate.
3) Inter area mode:- The oscillation frequencies are low in the range of 0.2 to 0.5 HZ. Inter area modes in which generators over an extensive area participate.

Low frequency electro-mechanical oscillation inherent to power system during transient condition. Power system disturbance such as line tripping and drop of generation cause local and inter area oscillation. It is necessary to pay attention to keep the stability and security of the electrical power system to prevent blackout.

The PSS are design mainly to stabilize local and inter area modes. However care must be taken to avoid interaction with intra plant oscillation mode which can become unstable.

TCSC can damp inter area power oscillations, regulating the power flow on a transmission line, mitigation SSR and improve transient stability.

The PSSs are effective in the oscillation damping. However there may be cases where the system PSSs are not able to suitably damp inter area oscillations mode. In such cases the simultaneous use of both controller type PSS and TCSC damping controller are required to guaranty a good closed loop system performance.

II. INTRODUCTION OF PSS

The basic function of PSS is to add damping to the generator rotor oscillations by controlling its excitation using auxiliary stabilizing signals.

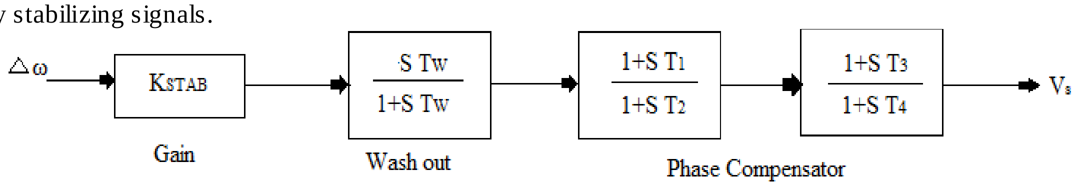

Figure 1:- Block diagram of delta-omega PSS[1]

The stabilizer gain value is normally set to a value that results a high critical system modes of oscillations. The value of washout time constant (Tw) should be high enough to allow signals associated with oscillations in rotor speed to pass unchanged. Tw may be anywhere in the range of 1 to 20s. To damp rotor oscillations, the PSS must produce a component of electrical torque in phase with rotor speed deviation. The basic function of Phase compensator is provide phase lag. Phase lag compensator design in such a way so that it provides damping to the oscillation at which are local modes of oscillations as well as inter area oscillation.

III. Introduction of TCSC

TCSC is a series FACTS device which allows rapid and continuous changes of the transmission line impedance. TCSC include series capacitor and TCR is placed across the capacitor.

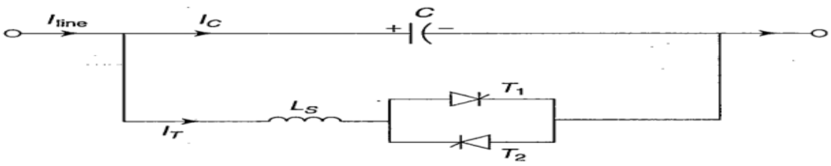

Figure 2:-TCSC basic circuit diagram [16]

- **Basic principle of TCSC:-**

A TCSC is a series controlled capacitive reactance that can provide continuous control of power on the ac line over a wide range. The principle of variable series compensation is simply to increase the fundamental frequency voltage across an fixed capacitor in a series compensated line through appropriate variation of the firing angle. This enhanced voltage changes the effective value of the series capacitive reactance. The equivalent impedance Zeq of this LC combination is expressed as

$$\mathrm{Zeq} = \left(\frac{j}{\omega c}\right) || (j\omega L) = -j\left(\frac{1}{\omega C - \frac{1}{\omega L}}\right)$$

If $\omega C - (1/\omega L) > 0$, The reactance of the FC is less than that of the parallel connected variable reactor. This inductor increases the equivalent capacitive reactance of the LC combination above that of the FC.
If $\omega C - (1/\omega L) = 0$, a resonance develops that result in an infinite capacitive impedance. So this is unacceptable condition.
If $\omega C - (1/\omega L) < 0$, The LC combination provide inductance above the value of the fixed inductor.

- **TCSC characteristic:-**

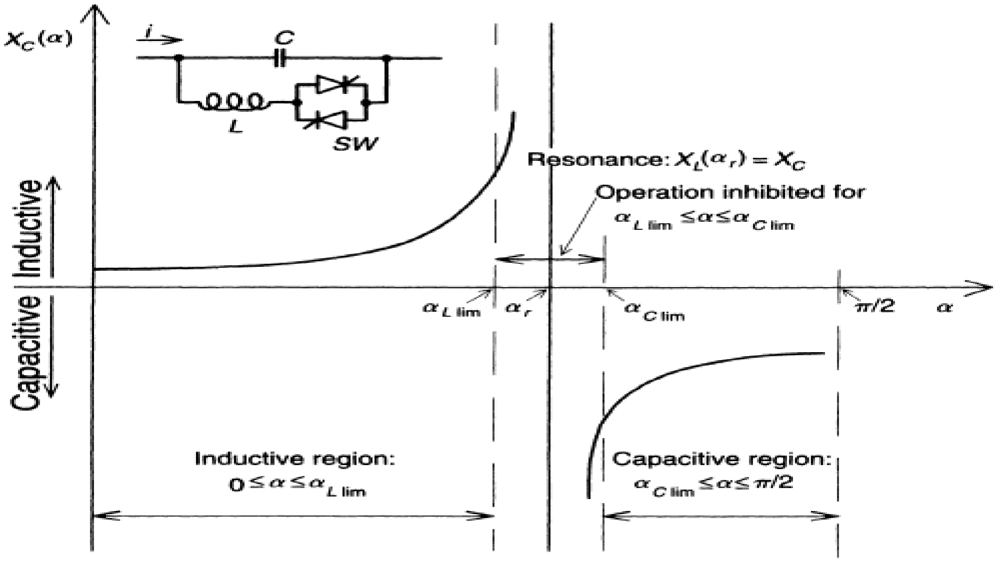

Figure 3 :- Variation of the TCSC reactance with firing angle[17]

In figure 3 the steady state impedance of the TCSC consisting of a fixed capacitive impedance Xc and a variable inductive impedance XL(α), Which is

$$\mathrm{XTCSC}(\alpha) = \frac{\mathrm{Xc}\ \mathrm{XL}(\alpha)}{\mathrm{XL}(\alpha) - \mathrm{Xc}}$$

Where,

$$XL(\alpha) = XL\frac{\Pi}{\Pi - 2\alpha - \sin\alpha}, XL \leq XL(\alpha) \leq \infty$$

Where XL= ωL and α is the delay angle

As the impedance of the controlled reactor XL(α) is varied from its maximum (infinity) towards its minimum ωL, the TCSC increases its minimum capacitive impedance, XTCSCmin = Xc = 1/ωC, until parallel resonance at Xc = XL(α) is established and XTCSCmax becomes infinite.

Decreasing XL(α) further, the impedances of the TCSC, XTCSC(α) becomes inductive, reaching its minimum value of Xc XL/(XL-Xc) at α=0, Where the capacitor is in effect bypass by the TCR.

The TCSC has two operating range around its internal circuit resonance:-

1) αclim ≤ α ≤ Π/2 range, where Xtcsc(α) is capacitive
2) 0 ≤ α ≤ αlim range , where Xtcsc(α) is inductive

IV. EXPERIMENTAL SETUP OF WSCC9 BUS SYSTEM WITH PSS AND TCSC

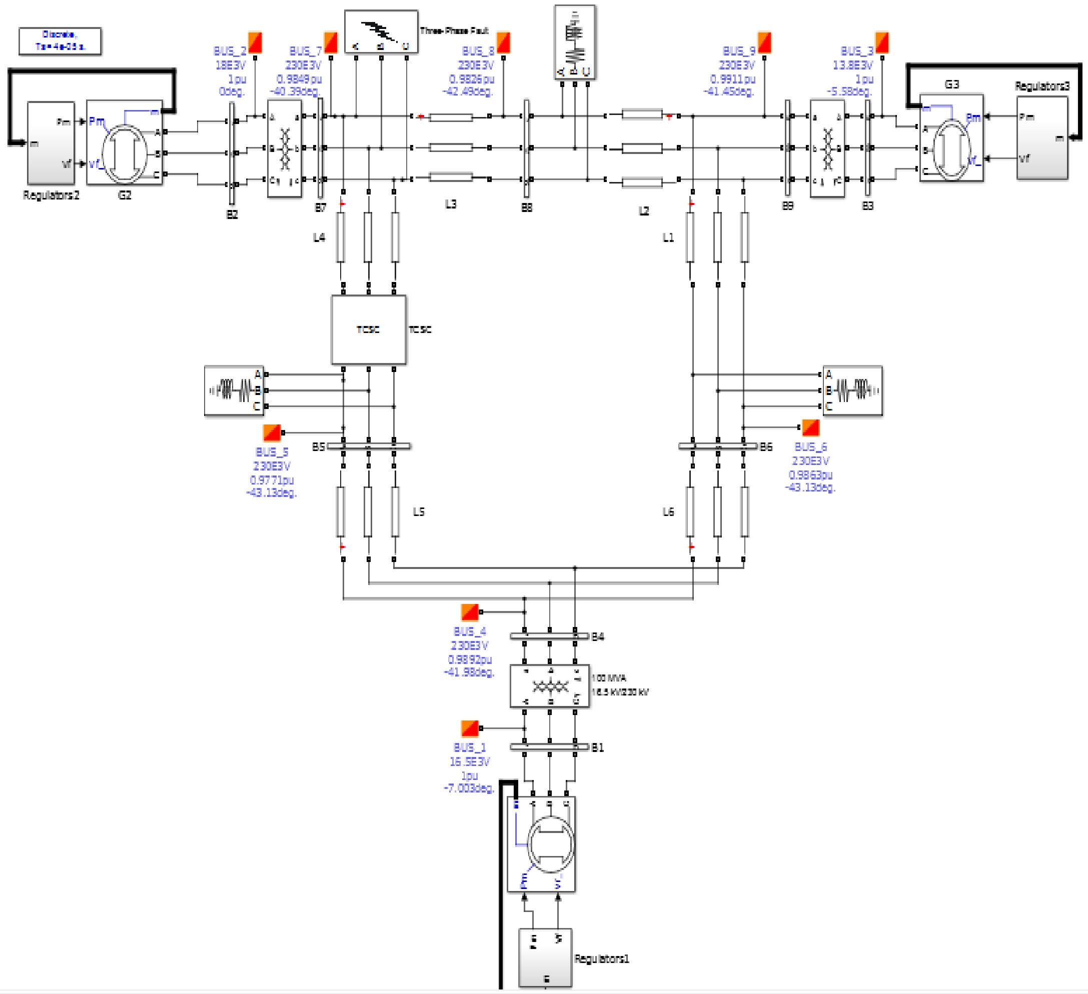

Figure 4:-Simulation of WSCC9 bus with PSS and TCSC

V. ANALYSIS OF SIMULATION RESULT

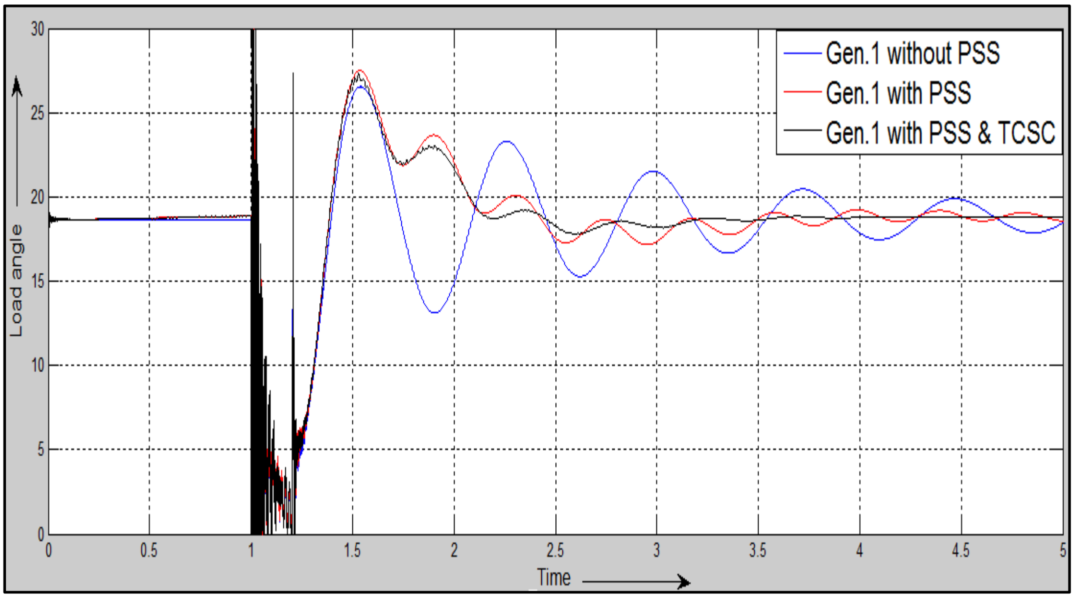

Figure 5:- Load angle delta of generator 1

Figure 5 shows that load angle Vs time graph of generator 1. Oscillations occur in the generator 2 load angle affect the load angle of generator 1. Load angle of Generator 1 without PSS can stable after 20sec. Load angle of gen.1 with PSS can stable in 6.9sec. and Load angle of Gen.1 with PSS & TCSC can stable in 3.8sec.

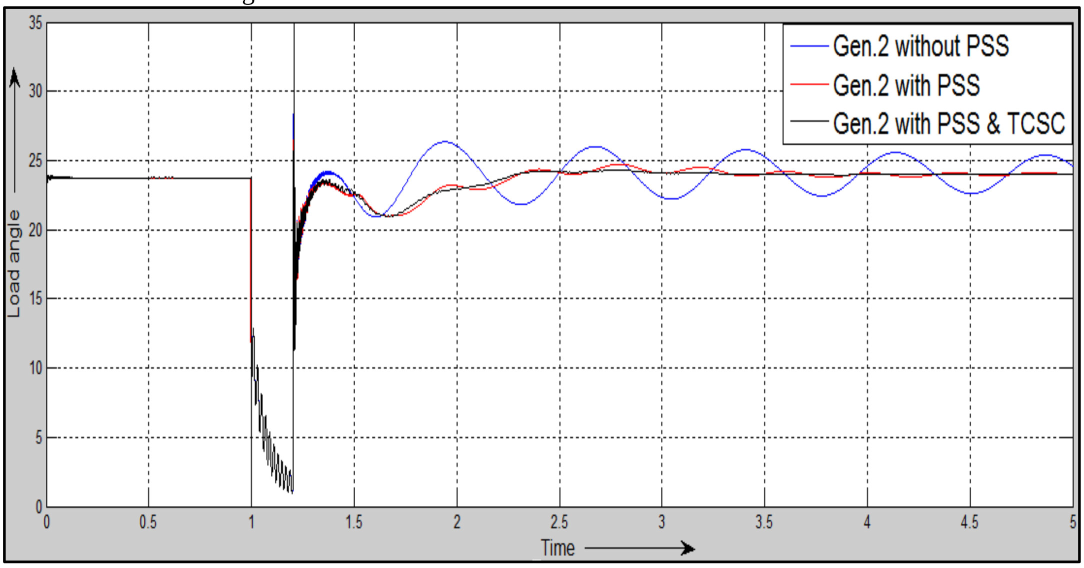

Figure 6:- Load angle delta of generator 2

Figure 6 shows that load angle Vs time graph of generator 2. Here in WSCC9 bus system, fault occurs nearer to the generator 2. So that oscillations occur in the generator 2 is maximum. Load angle of Generator 2 without PSS can stable after 20sec. Load angle of gen.2 with PSS can stable in 7.2sec. and Load angle of Gen.2 with PSS & TCSC can stable in 4.2sec.

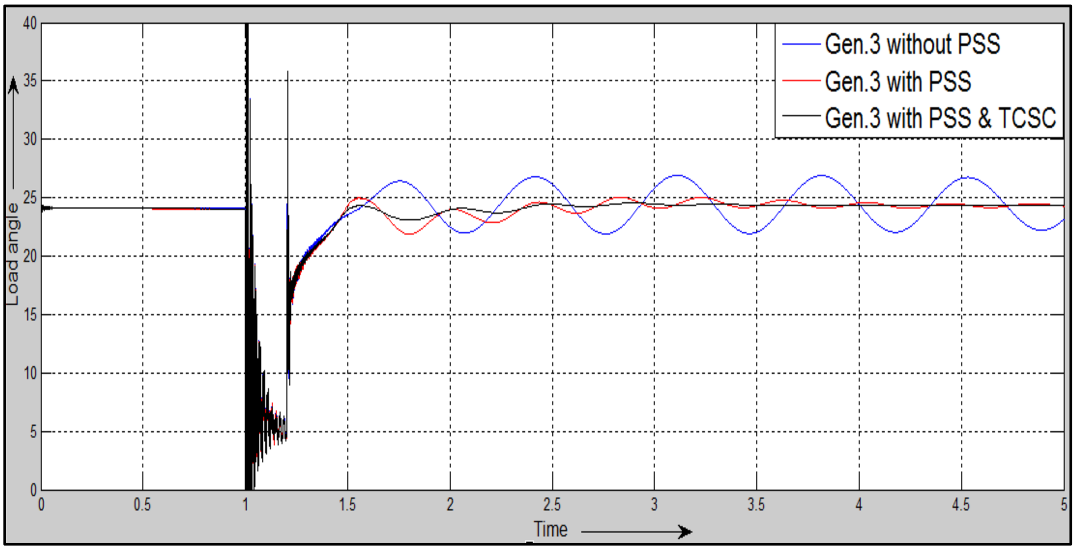

Figure 7:- Load angle delta of generator 3

Figure 7 shows that load angle Vs time graph of generator 3. Here in WSCC9 bus system, fault occurs nearer to the generator 3. So that oscillations occur in the generator 2 load angle affect the load angle of generator 2. Load angle of Generator 3 without PSS can stable after 20sec. Load angle of gen.3 with PSS can stable in 7.0sec. and Load angle of Gen.3 with PSS & TCSC can stable in 3.9sec.

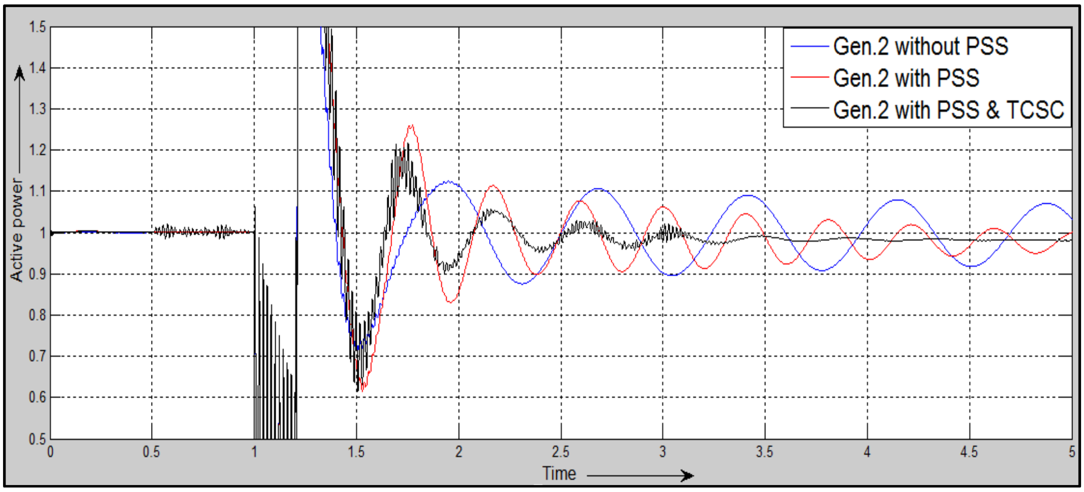

Figure 8:- Output active power in pu of generator 2

Figure 8 shows that active power Vs time graph of generator 2. Here in WSCC9 bus system, fault occurs nearer to the generator 2. So that oscillations occur in the generator 2 load angle is maximum. Hence there are oscillation occur in active power is max. Active power of Generator 2 without PSS can stable after 20sec. Active power of gen.2 with PSS can stable in 7.9sec. and Active power of Gen. 2 with PSS & TCSC can stable in 4.4sec.

CONCLUSION

In this paper, Coordinated control of Power system stabilizers and TCSC controller based damping reduction technique is discussed. The simulation of WSCC9 bus system with PSS and TCSC is carried out in MATLAB software. The simulation results show that the test system dynamic performance and overall damping effect are enhanced by simultaneous tuning of PSS and TCSC controllers. Therefore, WSCC9 bus system with PSS and TCSC provides better damping of power oscillations.

	Without PSS	With PSS	With PSS & TCSC
Generator 1	More than 20sec.	6.9 sec.	3.8 sec.
Generator 2	More than 20sec.	7.2 sec.	4.2 sec.
Generator 3	More than 20sec.	7.0 sec.	3.9 sec.

APPENDIX

- **WSCC9 bus system**

WSCC is a Western system co-ordinate council. WSCC9 bus system consists of 3 machines and 9 buses.

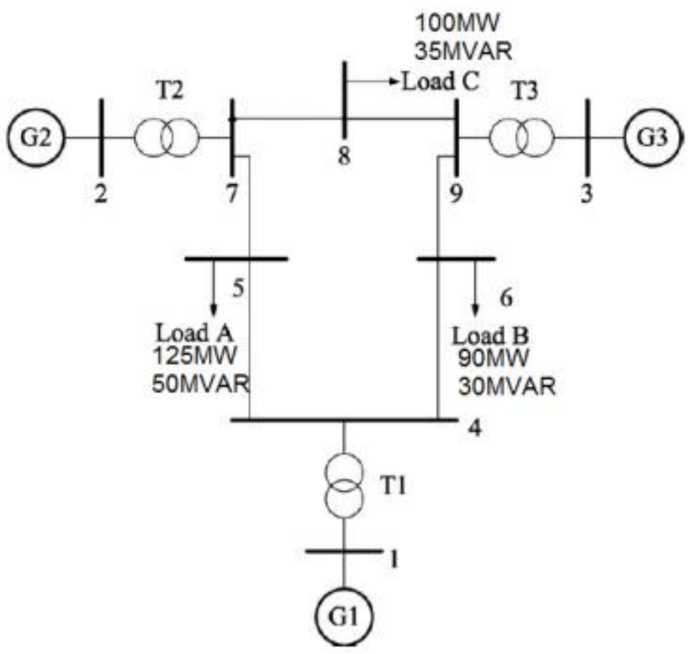

Figure A :- WSCC9 bus system[7]

Table no. D:- Bus data for WSCC9 bus system

Bus no.	Bus Type	Pg	Qg	PL	QL	Voltage Magnitude	Bus KV
1	Swing	_	_	0	0	1.04	16.5
2	PV	0.163	_	0	0	1.0253	18
3	PV	0.85	_	0	0	1.0253	13.8
4	PQ	0.0	0	0	0	-	230
5	PQ	0.0	0	1.25	0.5	-	230
6	PQ	0.0	0	0.9	0.3	-	230
7	PQ	0.0	0	0	0	-	230
8	PQ	0.0	0	1	0.35	-	230
9	PQ	0.0	0	0	0	-	230

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