Controlled Interphase Power Controller (IPC) on the Base of Squashed Transformer

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***Abstract*—One of the perspective technical decisions in the field of management of modes of the electrical networks and systems are the Flexible Alternating Power Transmission Systems (FACTS) or Power Controllers.**

Most perspective of them is Interphase Power Controller (IPC) on the base of noncontrollable phase-shifting transformer with the three working windings connected in "delta" and constant shifting angle of 60^0. The analyses of its characteristics and working modes which are done in this paper are shone, then using multiwindings controllable transformer allows essentially to damage the required power of the phase-shifting transformer.

***Index Terms*—electrical networks and systems, Interphase Power Controller, multiwindings controllable phase shifting transformer, characteristics**

I. Introduction

By one of most often meeting variant in the foreign publications, Interphase Power Controller (IPC) is executed on the basis of the noncontrollable phase-shifting transformer with three windings connected in a triangle (delta) and with branches from its tops, Fig.1.

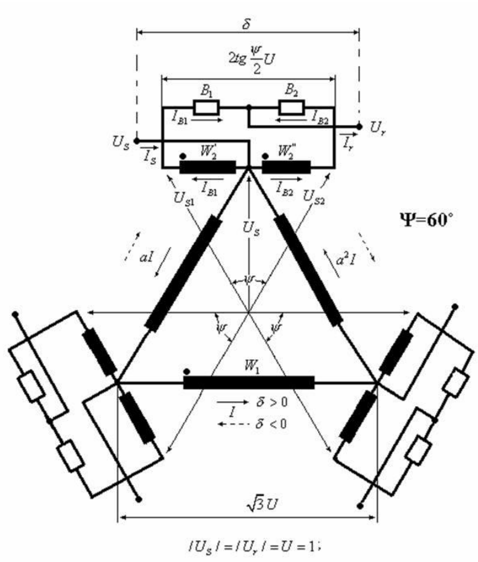

Figure 1. IPC on the basis of the noncontrollable phase-shifting transformer

One of the important parameters of the IPC is the ratio between its through power passage capacity and power of the phase-shifting transformer.

II. Squashed – delta connected multiwindings IPC

The researches have shown, that at the same controllable characteristics, the power of the phase-shifting transformer can considerably be reduced by using multiwindings shifting transformer.

In Fig.2 is shone the scheme of squashed – delta connected multiwindings IPC, at which the zone of regulation of the adjusting angle $\delta = \pm 30^\circ$ is provided by phase-shifting transformer with an angle $\psi = 30^\circ$, instead of 60^0 as in the previous variant.

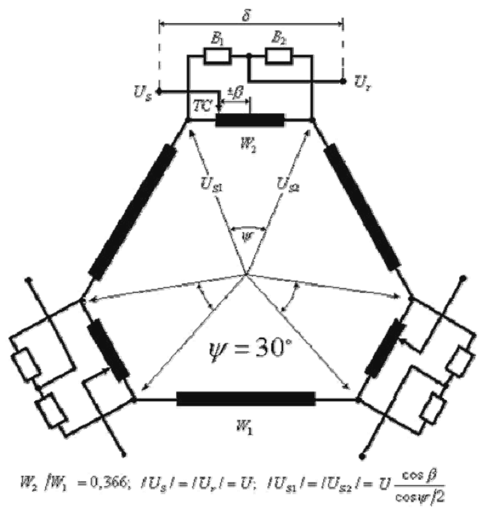

Figure 2. Squashed-delta connected multiwindings IPC

The basic feature of this scheme is, that the adjusting windings of the phase-shifting transformer are executed with adjusting branches removed on mobile contact of the mechanism of switching under loading (Tap Changer), which are connected directly to a supply voltage. In this case there is freedom of management as an additional ungle β° counted in both sides from the average point of adjusting winding (W_2), determined by some voltage (U_f) on the vector diagram, Fig.3.

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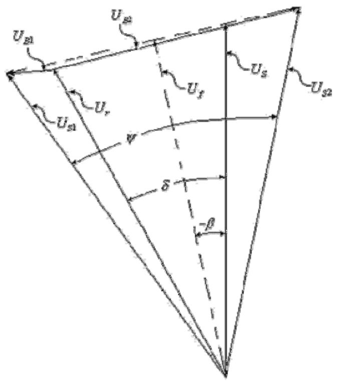

Figure 3. The vector diagram of the squashed delta - connected multiwindings IPC

During regulation, the angle $\psi = 30^\circ$ remains constant, but the powers characteristics $P_r(\delta)$ and $Q_r(\delta)$ are synthesized artificial, according to the law of regulation of the angle β. The basic equations of controlled IPC on Fig.2 are:

$$\begin{cases} P_r = S_{rm}\cos\beta\cdot\cos(\beta-\delta) \\ Q_r = S_{rm}\cos\beta\cdot\sin(\beta-\delta) \end{cases}, \quad (1)$$

where $S_{rm} = 2BU^2 tg\dfrac{\psi}{2}$.

Most simply is to realize the linear law of regulation of the angle $\beta = \dfrac{\delta}{2}$, which are shown in a Fig.4. As follows from the Fig.4, extreme points of the characteristic $P_r(\delta)$ at $\delta = \pm 30^\circ$ have risen up to a level 0.933, and the accompanying reactive power $Q_r(\delta)$ essentially (twice) has decreased after comparison with the squashed – delta connected IPC without adjusting winding, described in |1|. It means, that the characteristic $P_r(\delta)$ became considerably more rigid, and if it is necessary to recompense the output reactive power, the necessary power of cross reactor will be twice less. Thus, the power of the phase-shifting transformer S_{pr} makes only 0,423 from through passage power Sr.

The basic problem of a parametrical regulator of the power fluxes such as IPC is a maintenance of the active transmitted power, when the angle δ changes. Therefore the rigidity of the characteristic $P_r(\delta)$ is justified.

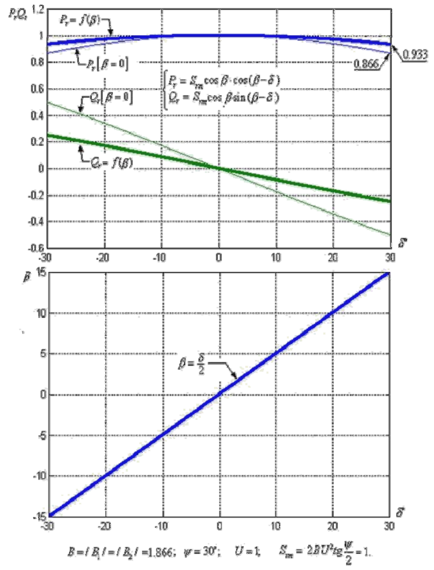

Figure 4. Linear law of regulation of the angle $\beta = \dfrac{\delta}{2}$

Accepting the condition $P_r = 1$ and having entered it in the equation (1), it is possible to receive the law of change of the angle β ensuring this condition:

$$\beta = arctg\frac{S_{rm}\sin\delta \pm \sqrt{S_{rm}^2\sin^2\delta - 4(1 - S_{rm}\cos\delta)}}{2} \quad (2)$$

The received law has the elliptic form and is submitted in the Fig.5. There are so shown in the Fig.5 the characteristics $P_r(\delta)$ and $Q_r(\delta)$. It is visible, that the characteristic $P_r(\delta)$ in the range of $\delta = \pm 22.5^\circ$ is absolutely rigid (horizontal straight) line. At the same time, characteristic $Q_r(\delta)$ appears split on two branches, i.e. at the same value of the angle δ we can receive two values of the reactive power Q_r. The zone Q_r covered with an ellipse, is a zone of regulation of the reactive power Q_r, which it is possible to ensure by insignificant deviation of the $P_r(\delta)$ from a direct line up to a level characterized with the law $\beta = \dfrac{\delta}{2}$ shown on the Fig.5. Thus, the introduction of the additional angle β is enough for regulation in to large limits the reactive power Q_r.

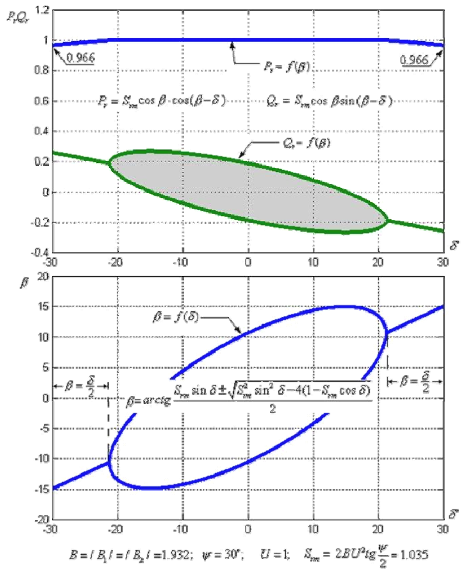

Figure 5. The working characteristics $P_r(\delta)$, $Q_r(\delta)$ and $\beta(\delta)$ of the squashed-delta connected multiwindings IPC

The further expansion of controllable ability of the device can be supplied by using special volts adding transformer, Fig.6. As follows from the basic scheme (Fig.6) the device consists from, placed in one tank phase-shifting transformer X and volts adding transformer Y, which has two secondary windings. The specified secondary windings are connected so, that the change of the regulation angle β was accompanied by change of the voltages of the device.

In this case, equation determining the output powers of IPC look as:

$$P_r = S_{rm}\cos\beta\left[\cos(\beta-\delta) - m\sin(\beta-\delta)\right]$$
$$Q_r = S_{rm}\cos\beta\left[\cos(\beta-\delta) + m\cos(\beta-\delta)\right], \quad (3)$$

where: $m = \frac{\sqrt{3}}{2}K_Y = \frac{\sqrt{3}}{2}0.309 = 0.268$.

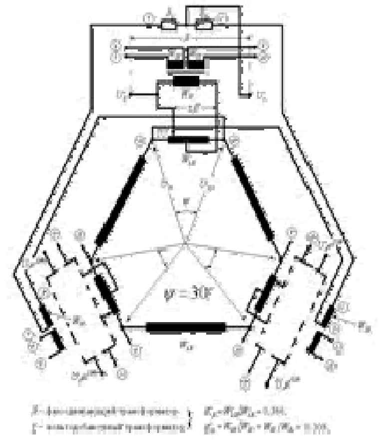

Figure 6. Squashed-delta connected multiwindings IPC with volts adding transformer

At the given $K_Y = 0.309$, the maximal value of the additional voltage entered into a circuit of loading by volts adding transformer will be:

$$U_{2Y} = U_{3Y} = K_Y\left|U_S\right|\sin\frac{\psi}{2} = 0.08\left|U_S\right| \quad (4)$$

To take in to account, then the volts adding transformetr has two secondary windings, the own power of the volts adding transformetr will be equal to $0.16S_r$. The most attractive feature of examined variant IPC is the opportunity of maintenance in a range of $\delta = \pm 30^\circ$ a condition $P_r = 1$ and $Q_r = 0$ (at observance of the law $\beta = \delta/2$). Thus, considered variant of IPC provides ample opportunities of influence on the form of the characteristics $P_r(\delta)$ and $Q_r(\delta)$ in comparison with noncontrollable variant of the device at essential smaller power of the phase-shifting transformer

REFERENCES

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