Smart Relays: Application of Support Vector Machine Classifier in Power Grids

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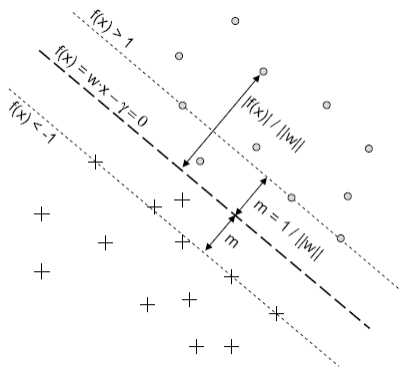
Goals

Build More “intelligent” relays to meet the security and reliability needs of the power grid in the future. Improve the performance of smart protection relays, so that they can discriminate between normal and faulty conditions accurately in complex large-scale systems.

Technology



To improve the accuracy of smart relays on complex conditions, *magnitude of current*, *phase of current, magnitude of voltage, phase of voltage, real power and reactive power* are all candidate features in SVM based smart relays.

$$\begin{pmatrix} 0.4291 & 0.3859 & 0.0345 & 0.5703 & 0.5838 & 0.8948 \\ 0.3071 & 0.1644 & 0.5107 & 0.5737 & 0.5696 & 0.3597 \\ 0.2500 & 0.1013 & 0.6054 & 0.5611 & 0.4636 & 0.4200 \\ 0.3513 & 0.9925 & 0.4710 & 0.6141 & 0.3856 & 0.5107 \\ 0.2187 & 0.2491 & 0.2356 & 0.5624 & 0.6003 & 0.7405 \\ 0.3706 & 0.9790 & 0.4482 & 0.6210 & 0.3783 & 0.5290 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \end{pmatrix}$$

Typical scaled feature space

Magnitude of current, phase of current, magnitude of voltage, phase of voltage, real power, reactive power, respectively are candidate features

Approach

1) Features Selection

Principal Components Analysis (PCA) is applied before SVM training. PCA points out that the real and reactive power carries the most information among all the 6 candidate features. However, the magnitude of current, which is the most common feature used in conventional relays, carries only a little information.

6 Features					
Train in Noise Free Test in Noise Free		Train in Noise Free Test in Noise		Train in Noise Test in Noise	
Train Accu.	Test Accu.	Train Accu.	Test Accu.	Train Accu.	Test Accu.
96.8351%	96.5342%	96.8351%	96.4354%	96.7204%	96.6265%

3 Features: Real Power, Reactive Power and phase of Voltage					
Train in Noise Free Test in Noise Free		Train in Noise Free Test in Noise		Train in Noise Test in Noise	
Train Accu.	Test Accu.	Train Accu.	Test Accu.	Train Accu.	Test Accu.
96.4824%	96.3497%	96.3149%	96.3366%	96.2048%	96.1386%

2 Features: Real Power and Reactive Power					
Train in Noise Free Test in Noise Free		Train in Noise Free Test in Noise		Train in Noise Test in Noise	
Train Accu.	Test Accu.	Train Accu.	Test Accu.	Train Accu.	Test Accu.
95.1071%	95.1044%	95.1071%	95.0254%	95.1336%	95.0913%

Approach

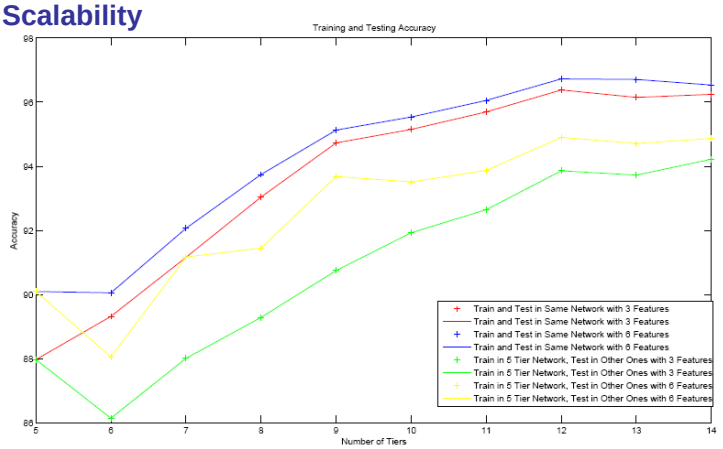
Linear Threshold VS. Non-Linear Threshold

Nonlinear Threshold delivers better performance, especially when fewer features are used.

	Training Accuracy for All	Testing Accuracy for All	Testing Accuracy for Zone1 Fault	Testing Accuracy for Zone2 Fault
Linear Kernel	98.55%	97.65%	100%	98.15%
Non-linear Kernel	99.63%	98.82%	100%	98.89%

	Training Accuracy for All	Testing Accuracy for All	Testing Accuracy for Zone1 Fault	Testing Accuracy for Zone2 Fault
Linear Kernel	85.6167%	85.8333%	100%	93.15%
Non-linear Kernel	98.22%	98.19%	100%	97.25%

Scalability



Conclusion

Support vector machine classifier based smarter relays differ from conventional ones in three aspects:

- They keep classifiers which is determined via SVM training;
- They sample the features needed on line, and make quick decisions using these online data;
- They can update the SVM classifier online, to keep the high accuracy when the system conditions change;
- They are scalable.

Acknowledgement

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Reference

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